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This project was undertaken to provide detailed information on the environmental impacts associated with outer continental shelf (OCS) pipelines. The report is designed to be used by scientists or engineers involved in offshore petroleum pipeline planning, pipeline corridors, and pipeline landfalls. Major technical and environmental constraints discussed include physical, geological, and biological characteristics of suggested sites.

Factors influencing site selection, such as coastal topography adjacent to offshore development areas, economics, existing onshore infrastructure, and state and local coastal policy are also presented. Emphasis is placed on the site, high-lighting site specific methods of installation and restoration.

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PIPELINE LANDFALLS:
A HANDBOOK OF IMPACT MANAGEMENT TECHNIQUES

by

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Interagency Agreement EPA-78-D-X0063

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PREFACE

In 1977, the New England/New York Coastal Zone Task Force, a group affiliated with the New England River Basins Commission (NERBC) and made up of state coastal zone program managers, recommended that the U.S. Environmental Protection Agency (EPA) initiate a research project on the environmental impacts of oil and gas pipeline construction and operation. The Task Force felt that should oil and/or gas be found on the region's outer continental shelf (OCS), they would need this type of information to make sound decisions regarding OCS pipeline routing. EPA, recognizing NERBC's continuing interest in OCS-related activities, responded with a formal request that NERBC undertake this project, entitled "OCS Pipeline Construction and Operation: Potential Environmental Problems and Recommendations for Mitigation of Impacts." Work was begun in January 1978.

Two final reports have been completed thus far. One report, "North Sea Pipelines: A Survey of Technology, Regulation and Use Conflicts in Oil and Gas Pipeline Operation," was completed in October 1979. In January 1980, a second report, "Choosing Offshore Pipeline Routes: Problems and Solutions," was issued. This report is the final in this series, all of which were prepared by the staff of the New England River Basins Commission under the sponsorship of the Municipal Environmental Research Laboratory-Cincinnati, U.S. Environmental Protection Agency.

ABSTRACT

This project was undertaken to provide detailed information on the environmental impacts associated with outer continental shelf (OCS) pipelines. The report is designed to be used by scientists or engineers involved in offshore petroleum pipeline planning, including pipeline corridors and pipeline landfalls.

Available methods are presented for managing environmental effects of pipeline installation at the landfall. Two basic techniques are available: (1) Choosing a site which has the fewest constraints to pipeline installation, and (2) using construction and restoration techniques which minimize the effects of installation-related activities at the chosen landfall.

The report provides an overview of factors which may be considered in evaluating potential pipeline landfall sites. Major technical and environmental constraints discussed include the physical, geological, and biological characteristics of suggested sites. Other factors influencing site selection, such as coastal topography adjacent to offshore development areas, economics, existing onshore infrastructure, and state and local coastal policy are also presented.

Because other considerations may cause final selection of landfall sites with less favorable natural characteristics, emphasis is placed on the site itself, highlighting site-specific methods of installation and restoration designed to minimize the potential effects of pipeline installation in both more and less favorable coastal systems. Past experience indicates that environmentally acceptable landfall installation is possible under unfavorable conditions with the use of such methods.

Two approaches are considered: (1) Alteration of technical construction and restoration methods to fit the constraints present at a particular landfall, and (2) preinstallation planning by government and industry officials to insure that construction methods selected address both technical requirements and environmental concerns posed by the chosen landfall. Specific examples of North Sea and Gulf Coast installations are used to illustrate technical methods which have been applied

successfully to minimize pipeline effects in a variety of coastal ecosystems.

This report is submitted in fulfillment of Interagency Agreement No. EPA-78-X0063 by the New England River Basins Commission under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period March 1, 1979, through August 10, 1980, and work was completed as of August 10, 1980.

CONTENTS

Preface ii
Abstract iii
- 1. Conclusions and Recommendations 1
- 2. Choosing a Landfall Site: The First Step 5
  - The "Straight Line" Route--Defining Preliminary Landfall Sites 6
  - Landfall Site Selection-- Physical Criteria . . . 7
    - Technical Considerations 7
    - Ecological Considerations 8
    - "Most Preferred" Landfalls 8
  - Landfall Site Selection--Socioeconomic Criteria . 11
    - The Adjacent Coastline 11
    - Economic Considerations 11
    - Legal and Coastal Policy Issues 11
  - Choosing a Landfall Site 12
- 3. Standard Landfall Installation Techniques 13
  - Beach and Dune Installation 13
    - Trench Excavation 13
    - Pipeline Installation 16
    - Restoration 18
  - Wetland Installation 25
    - Flotation Method 25
    - Push Method 28
    - Wetland Restoration 29
  - Special Installation Techniques 34
    - Highway and Railroad Crossings 34
    - Rock Blasting 36
- 4. Landfall Installations: Illustrations from the United States and North Sea 40
  - Long Beach, New York 40
  - Morgan, New Jersey 48
  - Grand Isle, Louisiana 56
  - Whiskey Pass, Louisiana 66
  - Cruden Bay, Scotland 73
  - St. Fergus, Scotland 81
  - Sullom Voe, Shetland Islands 88
  - Amlwch, Wales 101
  - Menai Straits, Wales 105
- 5. Landfall Case Studies: Planning Approaches to Minimizing Impacts 118
  - The Louisiana Offshore Oil Port (LOOP) 118

Development of Louisiana Deepwater Ports: Background 119
Pipeline Installation 122
Pipeline Right-of-Way Restoration Techniques and Regulations 128
The Far North Liquids and Associated Gas (FLAGS) Pipeline 142
FLAGS Line Siting and Regulations: Background 143
Pipeline Installation 146
Pipeline Landfall Restoration Techniques and Regulations 152
6. Minimizing Impacts at Future Landfall Sites 172
General Installation Techniques 172
Techniques for Specific Coastal Systems 175
Dunes 175
Cobble Beaches 176
Rock Cliffs 176
Wetlands 177
Use Conflicts 180
Planning Techniques 180
A Summary of Recommendations for Future Installations 185

References 187

Appendices

A. Industry's Procedures for Pipeline Landfall Selection 190
B. Legal Agreement on FLAGS Line Installation 192

SECTION 1

CONCLUSIONS AND RECOMMENDATIONS

One of the major concerns associated with offshore oil and gas is the transportation of petroleum from platform to shore. Although pipelines are generally accepted as the safest method of oil and gas transportation, their possible effects on the locations chosen as pipeline routes are still uncertain. This project, sponsored by the U.S. Environmental Protection Agency (EPA), is designed to provide information on the environmental effects of OCS oil and gas pipelines to officials in frontier areas who may become involved in planning pipeline routes from offshore development areas to land. This document presents methods for minimizing the environmental effects of pipeline installation at the landfall.

The report focuses on two major methods of minimizing potential impacts: choosing a site which has the fewest constraints on pipeline installation, and using construction and restoration techniques which minimize the effects of installation-related activities at the chosen landfall. Criteria are described for choosing or evaluating the relative environmental acceptability of various landfall sites and site-specific methods of pipeline installation and site restoration which have been successfully used to minimize effects both in more and less favorable coastal environments. Two types of site-specific techniques are considered: technical installation and restoration methods which specifically address the physical constraints of a particular site, and cooperative planning between government and industry to develop acceptable and effective regulations for a particular landfall. Specific examples of North Sea and U.S. installations are used to illustrate the effectiveness of these impact mitigation methods in addressing a range of possible constraints on pipeline landfall installation.

The major conclusion which may be drawn from these examples is that pipelines can generally be installed in most coastal systems with little evidence of environmental damage. The main exceptions are rock cliffs and wetlands. In the case of rock cliffs (where blasting is required), restoration with original materials is not possible; the concrete required to refill the trench may not be acceptable on ecological or aesthetic grounds. Because of their very loose sediment structure, wetlands (particularly those which are highly saturated) are probably the most difficult of all coastal ecosystems to restore to original aesthetic or functional condition. Only recently have large-scale restoration activities been attempted; although insufficient time has elapsed to draw final conclusions, early results of these restoration attempts appear very encouraging.

The following are suggested technical and planning methods which may be used to minimize the potential impacts of pipeline installation at a landfall. Although it is recognized that all these methods may not be usable in every instance, they should be considered in the evaluation of any proposed pipeline installation. In the final analysis, individual assessments of any landfall site will be necessary, and impact management methods and regulations must be developed based on the specific constraints of the site.

MANAGEMENT TECHNIQUE #1: LANDFALL SITE SELECTION

Landfall site selection is based on consideration of a number of physical criteria, including the physical/geological structure of the area and adjacent ocean, and the ecological systems at and adjacent to the landfall which may be affected by pipeline installation. Based on these criteria, geologically less favorable landfalls would include those with eroding shorelines, steep slopes, rocky coastlines, or high-velocity, nearshore currents. Biologically sensitive areas include wetlands, barrier beaches and islands, unstable sand dunes, and unique and/or rare or endangered species' habitats. More preferable would be coastal areas which are gently sloping (less than 10% grade), with sandy or firm sediments and no fragile or unusual habitats.

Other criteria (such as coastal topography adjacent to offshore development areas, economics, existing onshore infrastructure, and state and local coastal policy) may, however, cause final selection of landfalls with less favorable characteristics. The remaining methods focus on technical and planning techniques for minimizing potential impacts at the chosen site.

MANAGEMENT TECHNIQUES #2: TECHNICAL INSTALLATION METHODS

There are a number of methods for minimizing installation impacts which are appropriate for use in any coastal system. Although it is recognized that it may not always be possible to employ these techniques, they should be considered in planning any pipeline installation. General technical methods include:

- scheduling to avoid key ecological seasons to minimize impacts on local plant and animal species;
- minimizing the size of the area affected and, therefore, the extent of impact;
- restoring the land/water interface area immediately to minimize risk to landward coastal systems (e.g., wetlands or dunes); and
- restoring the entire affected area physically and ecologically to a condition as closely approximating the original as possible.

Certain coastal ecosystems require few additional methods to restore to original condition after installation activities have been completed. These areas include flat or gently sloping beaches with no dunes and industrialized or commercially developed waterfront areas.

The presence of other coastal features, such as dunes, cobble beaches, rock cliffs and wetlands, may require the use of more specialized methods to assure more complete functional and aesthetic recovery. These specialized technical restoration methods include:

- dunes--Artificial stabilization techniques (e.g., snow fences, gabions or Christmas tree tops) may be considered to assure dune recovery, particularly in coastal areas prone to wind or wave erosion. Dunes may be "naturally" stabilized by replanting with native vegetation.
- cobble beaches--Where blasting is necessary, non-native materials may be required for trench refilling and restoration of the beach form and function. In this case, new fill should approximate the general size, shape and distribution of original surface materials if possible.
- rock cliffs--As with cobble beaches, blasting for trench preparation will require refilling with non-native materials. In this case, however, it is likely that use of concrete would be necessary to restore functional integrity, making total aesthetic restoration impossible.
- wetlands--As stated previously, wetlands may be the most difficult of all coastal ecosystems to restore to

original functional or aesthetic conditions. Restoration programs would need to be designed on a case-by-case basis to address the key impacts expected in the affected wetland system.

MANAGEMENT TECHNIQUE #3: PLANNING METHODS

Increased government involvement in pipeline landfall siting and regulation will require coordination and interaction between the developer and public officials throughout project development. To encourage this cooperative planning and to facilitate development of acceptable and effective regulations for a particular installation, these planning methods may be considered:

- environmental assessment preparation -- This is an important means of identifying major potential impacts and information needs prior to construction.

- single agency planning and permitting -- This minimizes the time necessary to obtain permits and variances in original stipulations if necessary. It may also foster better communication between developers and regulators by clearly defining key participants in regulation development.

- ongoing consultation between developers and regulators -- This fosters development of installation stipulations appropriate to the landfall's technical and environmental constraints and allows flexibility to change original plans if necessary or desirable as construction proceeds.

- establishing restoration goals -- This focuses restoration efforts on minimizing major identified potential effects, rather than on attempting a complete replication of original conditions--which is often impossible to achieve except over a long-term natural restoration cycle.

- long-term monitoring programs -- These programs would provide a method for ongoing assessment of restoration success and the opportunity to identify and remedy, if necessary, an initially unsuccessful restoration effort.

SECTION 2

CHOOSING A LANDFALL SITE: THE FIRST STEP

A number of lease sales for OCS oil and gas development tracts are now underway in U.S. offshore areas previously not involved in petroleum activity. Although in light of the world petroleum situation this type of development seems certain, much concern is felt in these "frontier" areas regarding potential problems associated with offshore development.

One of the major sources of concern is the transportation of oil and natural gas from offshore platforms to the shore. Currently, there are two methods for transporting oil: tanker/barge or pipeline. Because of the high cost of liquefaction, the only practical method of natural gas transport is via pipeline. In the U.S., pipelines transport all the natural gas and most (95%) of the oil produced offshore to land (Shanks, 1978).

Although pipelines are generally accepted as the safest method of oil and gas transportation, there are still a number of concerns regarding their possible effects on the locations chosen as pipeline routes. Of particular concern is potential damage to sensitive environmental areas on and near the pipeline route from pipeline installation activities.

Previous studies (NERBC, 1980) have outlined the types and extent of anticipated damage which may result from offshore pipeline installation. Offshore trenching, and trenching and burial at the landfall, were considered likely to cause the greatest amount of environmental damage. However, when quantitative comparisons were made to other bottom-disturbing activities (bottom trawling, sea scalloping, etc.), pipeline trenching was shown to disturb significantly lesser quantities of bottom sediments. Therefore, it was concluded that when assessing the potential extent of disruption to the ecosystems along a proposed route, the major consideration should be the type of system and its sensitivity to damage, rather than the quantity of disturbance. Because the coastal zone contains a greater array of diverse and frequently fragile habitats than offshore areas, special attention should be given to potential environmental effects nearshore and at the landfall -- the location where the pipeline actually comes ashore.

Two general techniques for minimizing the possible effects of pipeline installation in the coastal zone and at the landfall are available:

1. to choose a site which has the fewest constraints on pipeline installation; and
2. to use construction and restoration techniques which minimize the effects of installation-related activities at the chosen landfall.

This section dicusses the first step--choosing a site--and provides an overview of factors which may be considered in evaluating and choosing among potential pipeline landfalls.

THE "STRAIGHT LINE" ROUTE--DEFINING PRELIMINARY LANDFALL SITES

During the first phase of offshore petroleum development in a frontier area, exploratory drilling is undertaken to determine the existence and extent of petroleum reserves in the lease sale area. During this exploratory phase, industry also begins initial planning for pipelines by selecting very generalized routes to carry potential "finds" to shore. Preliminary routes are delineated based on a few key criteria--the most important being the most direct path from the lease sale area to the shoreline. This minimum pipeline length is desirable to minimize pipeline construction and operation costs. (In 1979, average U.S. installation costs ranged from $375,000-$400,000 per mile for an 8-inch line to $850,000/mile for a 36-inch offshore line [Seaton, 1979]; North Sea offshore installation costs have reached $1.5 million/mile [NERBC, 1979].) From this most direct route, refinements to avoid hazard areas are made based on readily available offshore geological data. Additional modification may be made to more easily connect the offshore area to existing onshore transmission or processing facilities.

If commercial discoveries are made in the lease sale area, additional onsite data is gathered and the offshore route further refined. At this stage, a number of potential landfall sites may be identified by industry; the primary criterion remains, however, to minimize the length of the offshore pipeline. Therefore, even the preliminary selection of landfalls is made, in large part, based on their proximity to the commercial find location.

This basic "straight line" connection between offshore development areas and the shoreline is, therefore, the first criterion in landfall selection. By applying this first criterion, further attention can be directed at more clearly defined segments of the adjacent coastline from which potential landfall sites may be chosen. Preferred sites may then be chosen based on a comparative analysis of each location's physical advantages and constraints and its socioeconomic characteristics.

LANDFALL SITE SELECTION--PHYSICAL CRITERIA

An evaluation of the physical characteristics of a site focuses on two types of potential constraints--the physical/geological structure of the area and adjacent ocean, and the ecological system(s) at and adjacent to the landfall which may be affected by pipeline installation.

Technical Considerations

The technical feasibility of installing a pipeline at a proposed landfall can be determined by using criteria which industry has developed, based on minimizing construction difficulties and/or the risk of pipeline failure once operational. These criteria are based, to a large extent, on the geologic and physical characteristics of the site and the adjacent nearshore waters. Areas with the following characteristics would be avoided if possible:

- steep slopes--which would make pipeline installation and long-term stable restoration difficult;

- highly eroding shorelines--where pipelines would have to be buried extremely deeply to minimize the risk of future exposure;

- bedrock near the surface--which would require blasting for trenching;

- cohesionless sediments--which are very unstable and thus susceptible to bearing strength failures and sediment mass movements;

- high velocity nearshore currents--which can interfere with pipeline laying barges and equipment and necessitate structural measures (such as jetties) to maintain surf zone pipeline trenches (which would otherwise be quickly refilled);

- large tidal fluctuations--which would also interfere with pipelaying activity and which might necessitate deeper burial depths; and

- limited shoreline access-- which would limit the usefulness and efficiency of the landfall as a construction staging area.

Table 1 presents technical criteria for screening potential pipeline routes and landfalls developed by a consortium of gas pipeline companies as part of a survey of sites along the British coast. This survey was undertaken in anticipation of discoveries of additional offshore gas fields. These criteria, when taken together, represent an ideal routing situation; "real world" routes have often included many undesirable features because other considerations (such as economic factors) have outweighed the technical difficulties in construction (NERBC, 1979).

Ecological Considerations

The primary ecological constraint on pipeline landfall siting is the presence of sensitive environmental areas which may be easily disrupted by pipeline installation (particularly trenching operations) and which may take long periods of time to recover. These areas include:

- unusual and important habitats--such as rare or endangered species habitats, spawning and nursery areas, and areas of special ecological significance;
- habitats which are difficult to restore--because of their unique sediment or vegetation structure, or aesthetic qualities; and
- habitats with commercial value--such as shellfish beds.

"Most Preferred" Landfalls

Based on the technical and ecological considerations outlined above, certain coastal system types would be more desirable for landfalls than others. For example, those coastal areas which are gently sloping (less than 10% grade), with sandy or firm sediments and no fragile or unusual habitats or species would be most preferable for landfall siting. Unfavorable sites would be those which have characteristics such as eroding shorelines, steep slopes, high velocity nearshore currents, poorly consolidated sediments, or unique and/or rare or endangered species habitats.

Table 2 presents an overview of most and least preferred features of a variety of coastal ecosystem types including: beaches, beaches with dunes, barrier islands, bluffs, and wetlands. Based on these criteria, accreting sand beaches with no dunes have the fewest constraints, while marshes have the

TABLE 1

PHYSICAL CONSTRAINTS ON PIPELINE LANDFALLS

CRITERIA FOR EVALUATION

Onshore (above limit of marine activity)

1. 500 acres land with slope under five percent; well drained; average bearing capacity.
2. within one mile of coast; or
3. two sites with similar physical characteristics: one 50 acres within one mile of coast, one 500 acres within five-ten miles of the coast.

Coastal (from low water mark to upper limit of marine activity)

1. less than ten percent slope.
2. sediment at least three meters.
3. absence of unstable/very mobile sediments.
4. absence of hard untrenchable rock outcrops.
5. absence of high velocity currents.
6. absence of rock cliffs (ten meter high soft sediment cliffs permissible).
7. absence of unstable sand dunes.
8. space for landing two pipelines (100-200 meters).

Offshore (low water mark to depth of 100 feet)

1. less than ten percent slope, low to moderate undulation.
2. sediments at least two meters deep.
3. absence of mobile seabed sediments, especially sand waves.
4. absence of high velocity currents.
5. absence of untrenchable rock.
6. absence of deep trenches; other major seabed irregularities.
7. absence of minor seabed irregularities.

Source: NERBC, 1979, p.36.

TABLE 2

COASTAL ECOSYSTEM CHARACTERISTICS AFFECTING LANDFALL SELECTION

	Most Preferred Features	Least Preferred Features
Shoreline Sediments	Homogeneous (non-layered), stable high bearing strength, low water table, non-"runny" soils	Diverse texture layers, unstable low bearing strength, high water table, "runny" wet soils
Barrier Islands	Sandy ocean front, relative historical stability, little wetland or bay area landward of shore crossing	Heavy sediment ocean front, significant historical migration and tidal inlet formation, large wetland or bay expanse between island and mainland
Beaches	Accreting, sandy beach with historical stability (long-term and during storm activity)	Eroding, heavy sediment ocean front with a history of significant normal and storm-induced erosion
Onshore Sand Dunes	Small in size with historical erosion levels small in magnitude	Large in size with historical erosion levels large in magnitude
Wetlands	Firm soil conditions (high trafficability) with no obstructions such as tree stumps	Soft, muck soil conditions, (low trafficability) with many obstructions which are hard to remove
Bluffs	Small in size with a history of relative stability and no history as a run-off area	Large in size, with a history of erosion and recession from the water's edge, and a known run off point for upland storm, flood and waste waters

Source: after Rooney-Char and Ayres, 1978, p.104-106.

largest number of undesirable features.

LANDFALL SITE SELECTION--SOCIOECONOMIC CRITERIA

There are other criteria, however, which may also need to be considered in choosing a landfall site. These considerations include: coastal topography adjacent to the development area, economic considerations, and legal and coastal policy issues.

The Adjacent Coastline

Although a "straight line" route is the most desirable, "more preferred" coastal land types may not be available in the coastline adjacent to the lease sale area. In this event, two options are available: to alter the route so that a site with fewer constraints can be used for the landfall or, to use the less preferable site, modifying installation and restoration techniques to address the site's problems. (In either case, increased construction costs may be anticipated.)

Economic Considerations

In addition to the basic criterion of minimizing the length of the offshore pipeline route to minimize costs, there are other economic factors which industry considers in selecting a landfall. These include (Rooney-Char, 1979):

- rights-of-way acquisition costs--which vary by the existing land value, use, and ownership; and the number of pipelines to be installed (which will determine the width of right-of-way required);
- permit acquisition costs--which vary based on the number of permits required and the amount of supporting data (environmental, etc.) required for permit application; and
- construction and maintenance costs--which include construction outlays for design, equipment, and/or labor which vary based on pipeline specifications and the physical constraints on construction at the landfall; and operating costs including taxes, insurance, and amortization of the investment.

Legal and Coastal Policy Issues

The choice of possible landfall sites may also be affected by legal or policy constraints. These include:

- gaining permit approval--Multiple permits which require lengthy preparation and/or review also increase final project costs. The extent of public support and the possibility of court suits may also be considered in evaluating the relative benefits and costs of potential sites;

- existing land use/zoning--Certain coastal land uses (e.g., wildlife preserves or densely populated areas [particularly in the case of gas pipelines]) may preclude the area's availability for landfalls. Additionally, the need to obtain zoning variances would increase final project costs by lengthening the lead time required prior to commencing construction; and

- coastal zone management policies--States and/or localities may have coastal zone policies which specifically (or implicitly) encourage or discourage this type of development.

CHOOSING A LANDFALL SITE

Final site selection will likely be based on site-by-site evaluations using all these siting criteria and will depend on the relative weights given to each by the developer and the public officials involved in choosing the site. Industry's landfall site selection procedures are presented, in greater detail, in Appendix A.

Past experience indicates, however, that even in circumstances where less than ideal landfall sites must be chosen, environmentally acceptable pipeline installations can be accomplished.

The remainder of the report focuses on actual landfall installations in both more and less preferred coastal system types--highlighting the methods of installation and restoration which were developed to minimize the projected effects of pipeline installation on the chosen site. Before considering these mitigating measures, however, it is necessary to understand their causes -- the construction activities associated with pipeline installation.

SECTION 3

STANDARD LANDFALL INSTALLATION TECHNIQUES

This section describes basic landfall installation techniques which have been developed for use in specific coastal ecosystem types. Three methods are described in detail: the pull method -- utilized in most beach and dune landfall installations; the flotation method -- for installations in soft, muddy marshes and wetlands; and the push or shove method -- utilized for wetland installations with firmer, more stable soil. Special techniques for highway and railroad crossings and landfalls with extensive rock formations are also described.

Three basic aspects of the installation methods are described:

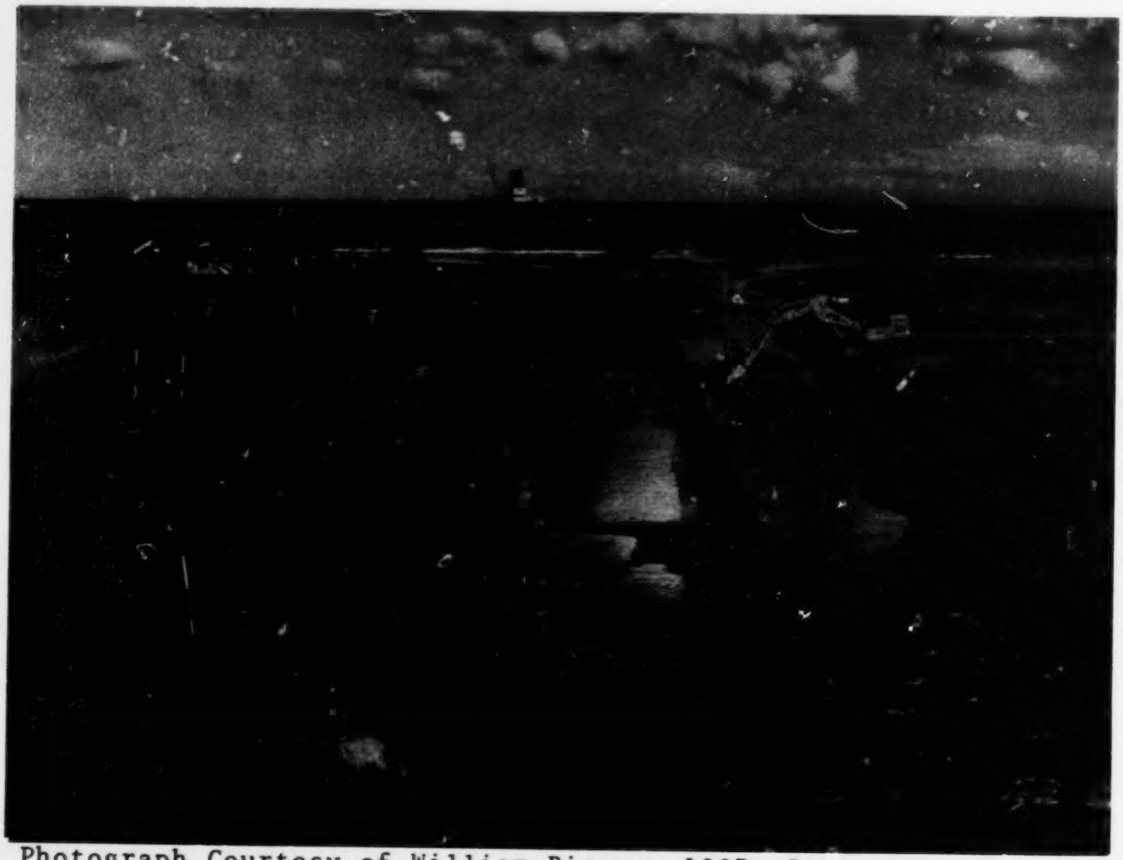
- Trench Excavation--This section describes the methods and equipment used in preparing the pipe trench or flotation canal.
- Pipeline Installation--This section describes the technical details of the pipe installation (use of winches, worksite setups, laybarge operations, etc.).
- Restoration--This section describes the basic techniques of trench refilling, revegetation and site restoration used in beach, dune, and wetland systems.

BEACH AND DUNE INSTALLATION

The pull method is the basic installation technique used in the following coastal systems: beaches, barrier beaches, beaches with dunes, and cobble or shingle beaches. Although these systems have a wide range of sediment types, from silts and fine sands to gravel, all have sufficient bearing capacity to support standard land excavation equipment, large winches, and heavy pipe welding and coating equipment.

Trench Excavation

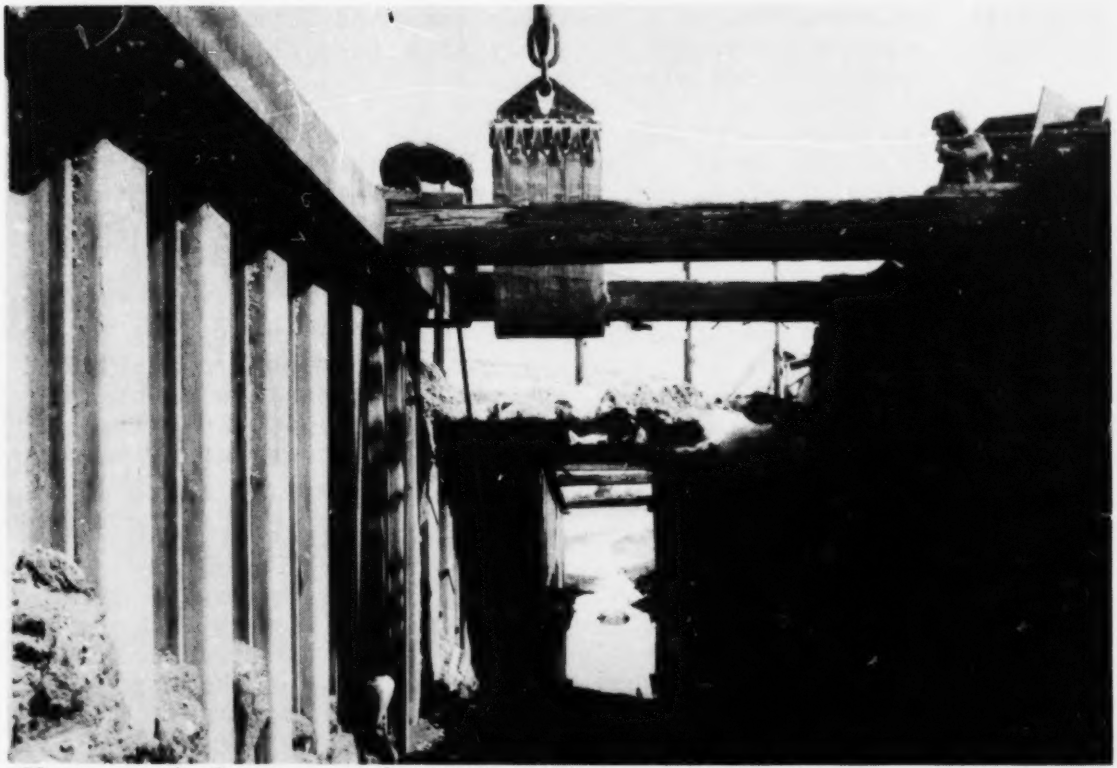
Onshore: The landfall site is surveyed and the pipe route and trench dimensions are carefully staked out. Land excavation equipment, usually backhoes (Figure 1), are then used to dig the trench.



Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 1. Land Excavators Digging Pipeline Trench.

For some landfall installations, sheet piling is used to line the trench (Figure 2). Sheet piles are driven into the sediments on both sides of the planned trench and the sand between excavated. Sheet piling is advantageous because it allows excavation of a narrow and stable trench to any desired burial depth. This is particularly useful in situations -- often sandy beaches -- where the sediment's angle of repose and degree of saturation would necessitate the excavation of a considerably wider trench if not sheet pile lined, to provide the same burial depth as a lined trench. Very deep burial may also be necessary in some sandy locations to protect the pipe from exposure due to erosion. Sheet piling is also advantageous



Photograph Courtesy of William Binger, LOOP, Inc.

Figure 2. Sheet Pile Lined Trench.

for narrow rights-of-way or where it is desirable to disturb as small an area as possible to limit environmental impact on a beach and dune system.

The sediments removed from the pipe trench (spoil) may be stored in a number of ways, including:

- storage on the beach adjacent to the trench;
- construction of a temporary jetty out from the beach into the surf zone. This jetty could provide a work platform for excavation of the pipe trench in the surf zone, and provide stability for the ditch once excavated;
- barging and deposition a short distance offshore to be returned to the beach system by natural processes or later dredged and returned to the beach; or

- construction of a causeway landward from the dunes to support construction activities (see Chapter 5 -- St. Fergus, FLAGS pipeline).

Special care is usually taken in the storage of materials excavated from the dunes. The upper vegetative layer and the inner core of sand are sometimes stored separately for later use in dune restoration. The materials are commonly stored behind the dunes where there is a degree of protection from wind and wave erosion.

Spoil piles stored onshore are generally stabilized to reduce the effects of wind erosion and water runoff. Stabilization can be accomplished using netting, vegetative plantings, clay-rich coverings, fences, thatching (pine bough covering), or stabilizing substances (e.g., Crelawn -- a waterbased bitumin material).

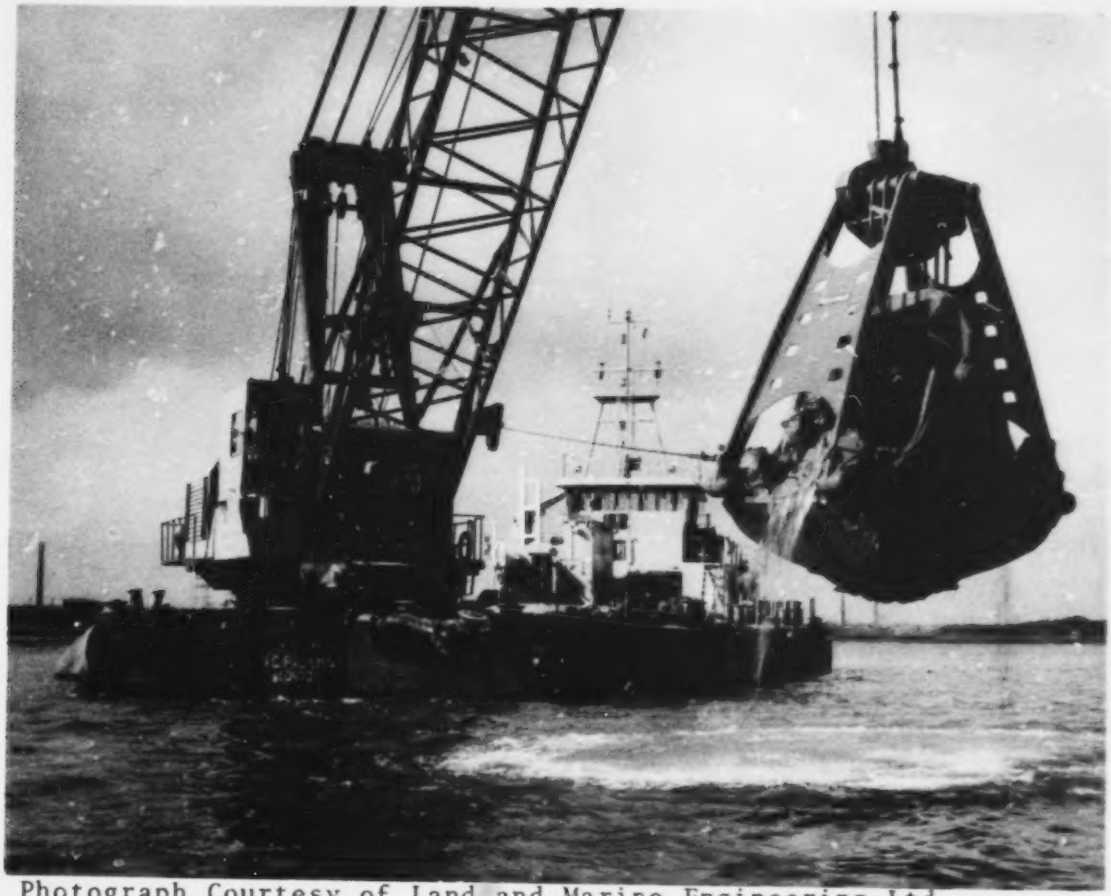
Nearshore/surf zone: The nearshore section of the pipeline trench is either pre-excavated by barge-mounted clamshell or dragline dredges, or the pipeline is buried after installation by submarine trenching machines (Figure 3). In water too shallow for barge operations, land-based equipment must be used. Land excavators can be operated in the surf zone on platforms built on a sheet pile trench lining (Figure 4) or a temporary jetty constructed of sand removed from the beach (Figure 5). Both sheet piling and jetties help prevent siltation (infilling) of the trench, particularly when the trench must remain open for an extended period of time.

Pipeline Installation

Two basic variations of the pull method are used for pipe installation -- a laybarge-based pull or a shore-based pull.

Barge-based pull: Lengths of pipe (joints) are first welded together into strings at a shore work area (Figure 6). The amount of work space available for string makeup and storage is the determining factor in the final length of the strings. For example, at Amlwch, Wales, a worksite of only about one-half acre was available for making up pipe strings and, as a result, only four joints (about 200 feet) could be welded together. By contrast, a worksite of 20-25 acres for the Menai Straits crossing in Wales allowed production of pipe strings over 1100 meters (3300 feet) long. After the joints are welded, the welds are coated with mastic and a layer of concrete.

A pulling head (Figure 7) is welded to the leading end of the first pipe string, a steel cable attached, and the wire connected to winches mounted on a barge anchored offshore. As each string is pulled offshore by the winches, another string is

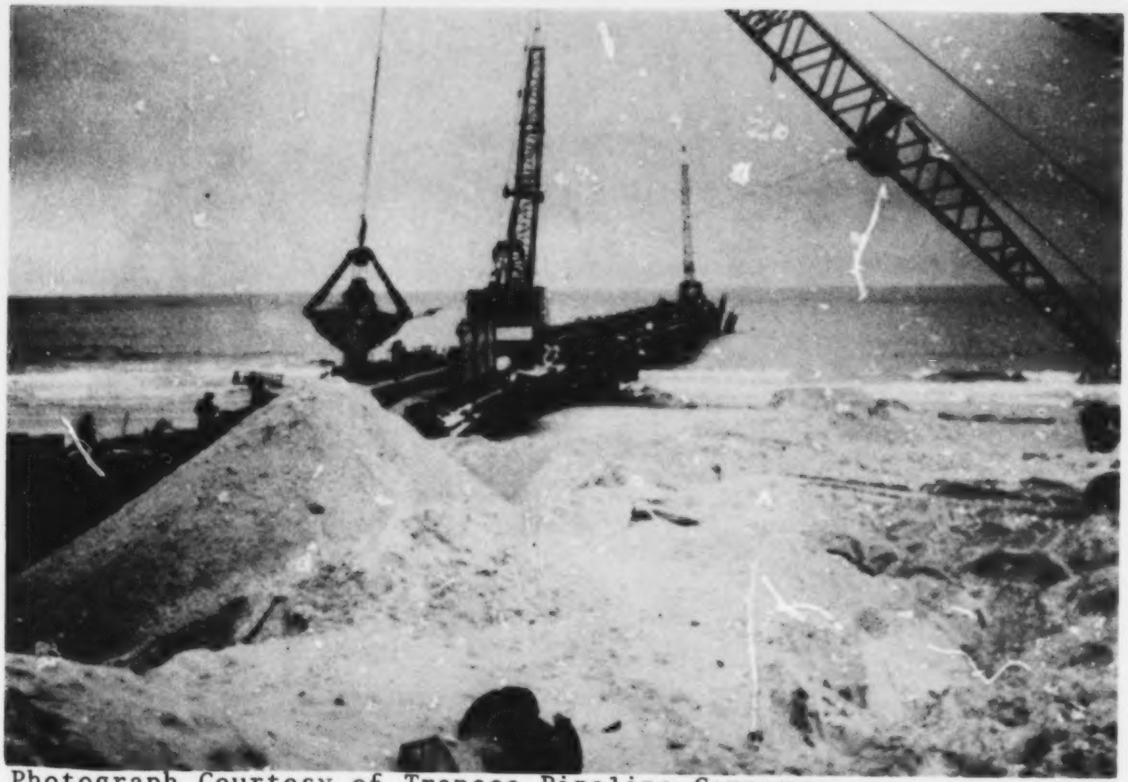


Photograph Courtesy of Land and Marine Engineering Ltd.

FIGURE 3. Barge-Mounted Clamshell Dredge.

rolled into position, welded to the previous string, the weld is coated, and the pull continued (Figure 8). Styrofoam or hollow metal floats can be attached at intervals to the pipe to reduce the dead weight of the pipe and pulling load; the pipe, however, still maintains contact with the bottom. To reduce friction in the onshore trench, the pipe is often passed over rollers (Figure 9).

Shore-base pull: For the shore-based pull, the staging area and winches are in opposite positions; winches are mounted at the shore worksite while the pipe is welded on an offshore barge. The winches operate at slow speeds, so that the completed pipe string is not pulled past work stations on the barge and proper tension can be maintained on the pipeline to



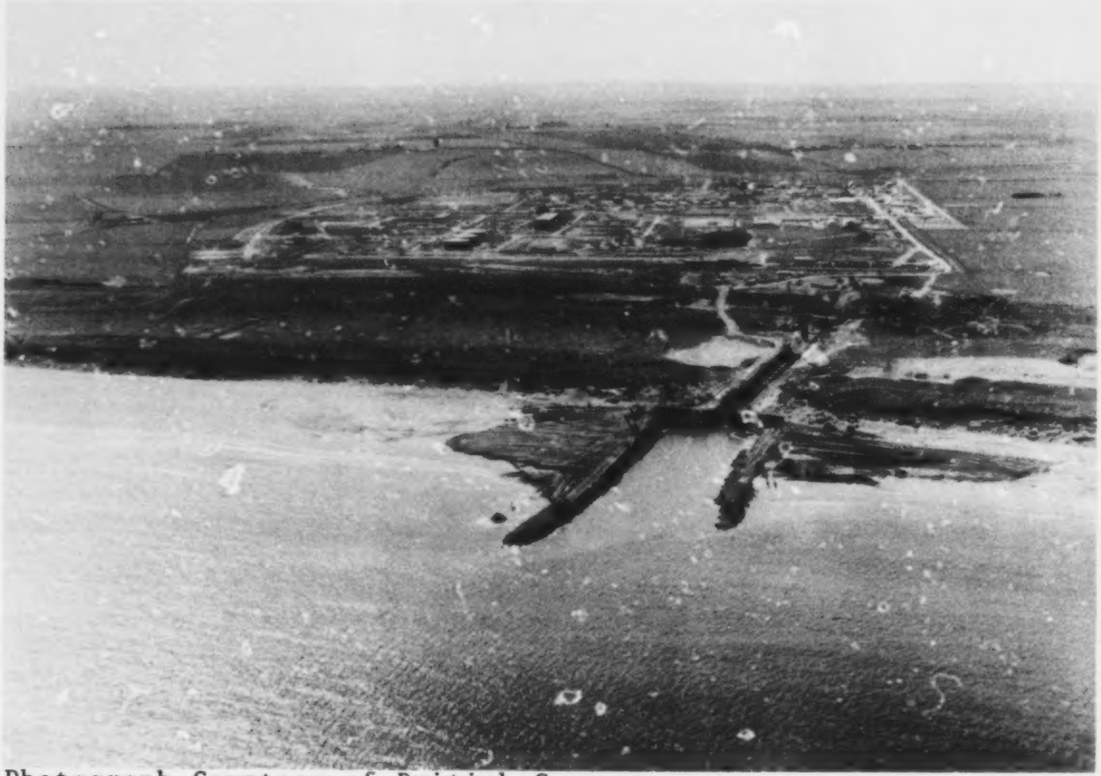
Photograph Courtesy of Transco Pipeline Company.

FIGURE 4. Land Excavation Equipment Operating on Sheet Pile Work Platform.

prevent buckling. When the pipe reaches the next work station, the winches are stopped, and a new length of pipe is welded into place. Figure 10 shows a typical shore-based pull winch site.

Restoration

The degree to which a beach landfall has to be restored will depend on a number of considerations which should be addressed before the start of construction. These include: the environmental sensitivity of the affected coastal systems; present and future use of the landfall and associated rights-of-way; governmental regulations or ordinances; and requirements or stipulations included in rights-of-way negotiations. The pipeline operator will consider these factors and specify the required restoration work that the pipeline construction contractors must include in their proposals and bids for a landfall installation project. The following sections discuss some of the techniques that may be used to restore a beach landfall.



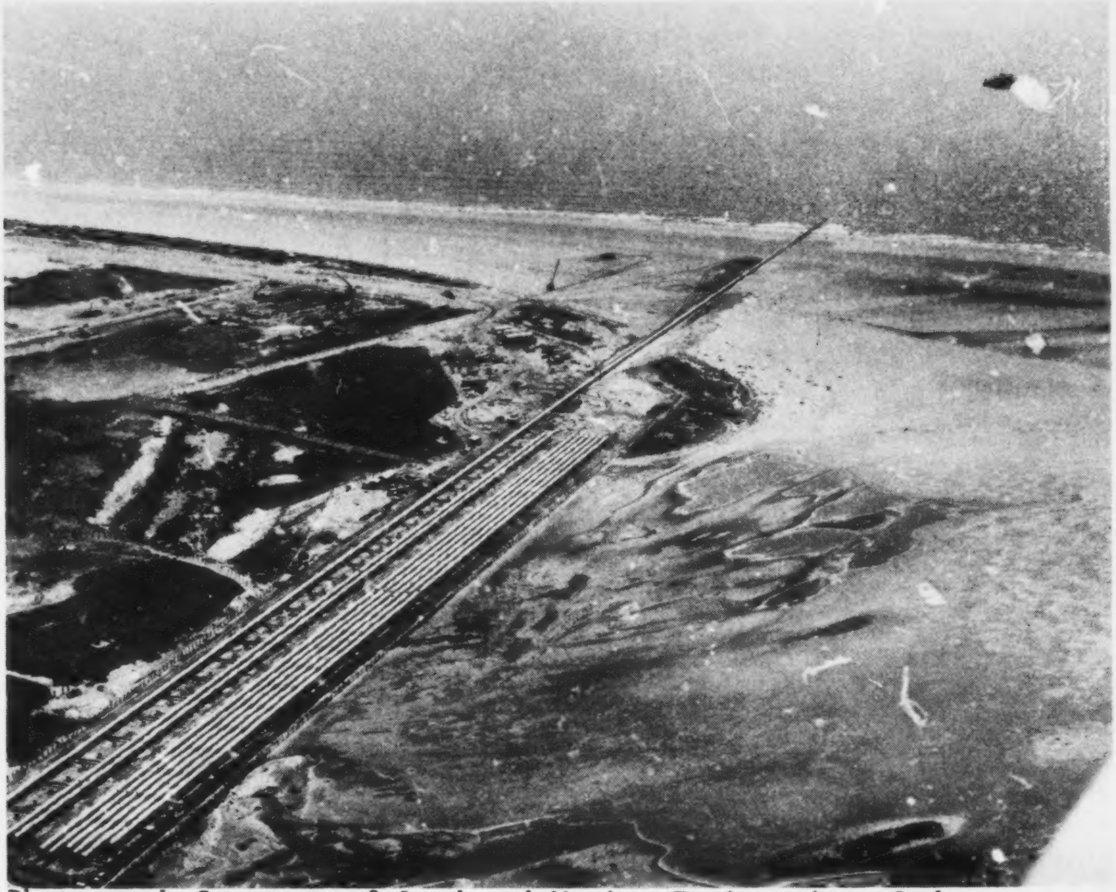
Photograph Courtesy of British Gas.

FIGURE 5. Dredge Operating on Finger-like Extension of Sand.

Foreshore/beach: The pipeline trench is usually refilled using the original material; sheet piling is next carefully graded to return the area to its original contours. Aesthetic recovery of the beach is relatively quick; functionally, however, the beach may be more vulnerable to wave erosion until natural resorting restores the sediments to equilibrium conditions for that particular beach.

On cobble or shingle beaches the trench is frequently refilled with original materials, although occasionally, it may be desirable to use clean gravel or armorstone fill to provide additional protection for the pipeline. Even if non-native materials are used, the upper layer of cobble or shingle is generally restored with original material or rock material that closely resembles the original in size distribution, shape, and density.

Dunes: The primary concern with dune restorations is to



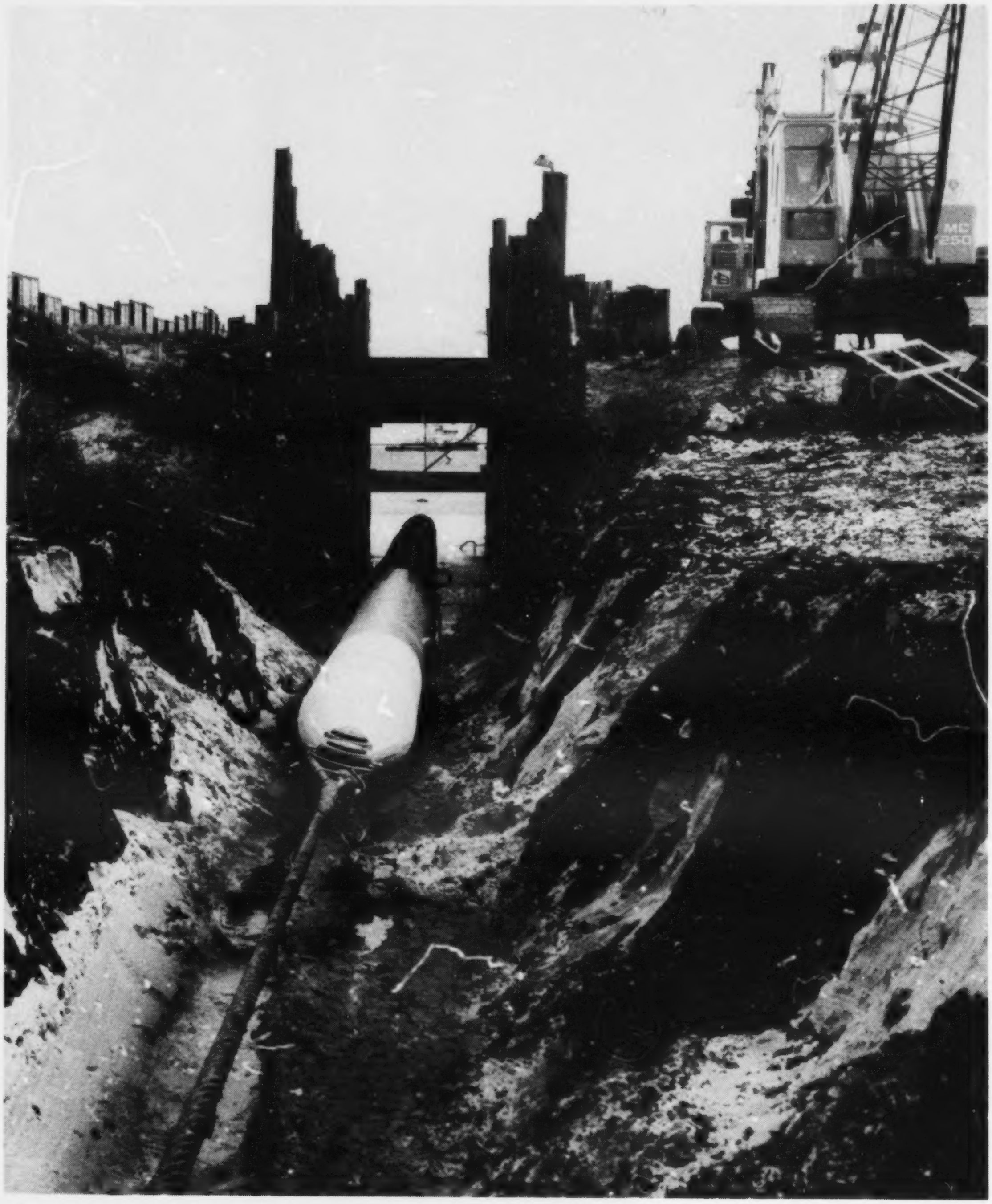
Photograph Courtesy of Land and Marine Engineering, Ltd.

FIGURE 6. Pipe Strings Made Up at Shore Work Site and Ready to be Pulled Offshore.

insure the dune's return to its natural protective function -- sheltering the back dune wetlands or other natural environments from wave attack and salt water inundation. The restoration should also protect the dune from wave erosion and wind-induced blowouts during the recovery period.

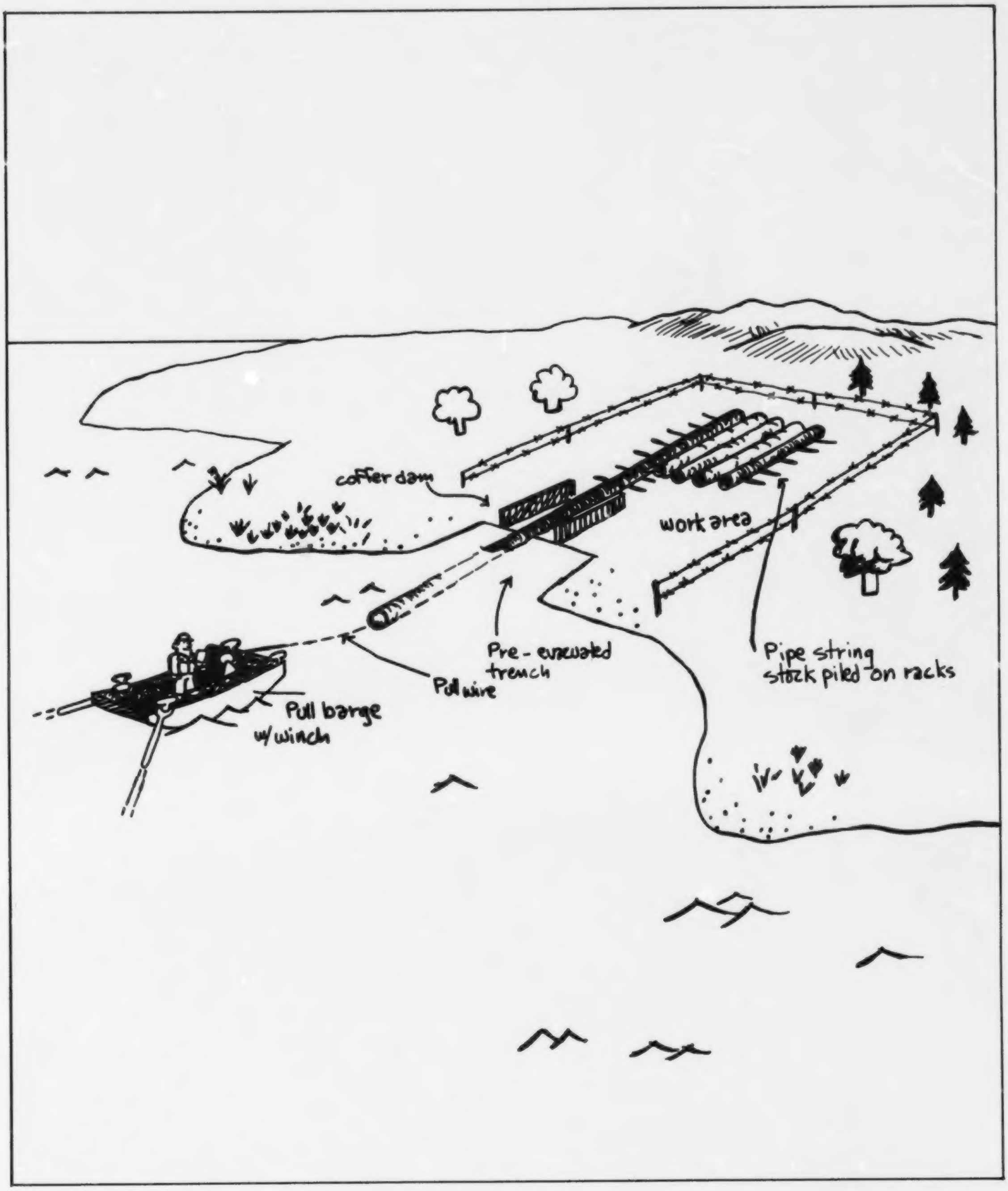
The first step in restoration -- refilling the trench -- can be accomplished in a number of ways:

- the original layers of dune sands may simply be replaced;
- layers of different materials (clay, crushed rock,



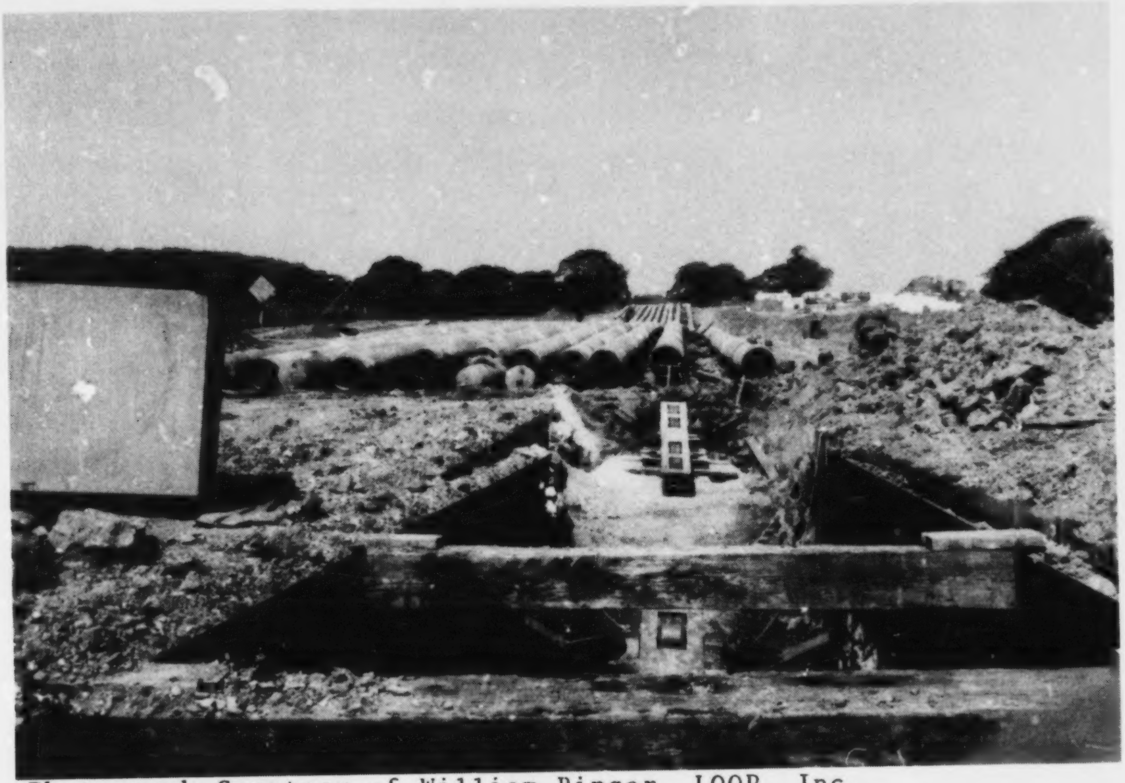
Photograph Courtesy of Land and Marine Engineering, Ltd.

FIGURE 7. Pulling Head and Steel Cable Attached to Head of Pipeline.


coffer dam
work area
Pre-evacuated trench
Pipe string stock piled on racks
Pull wire
Pull barge w/winch

Source: NERBC, 1981.

FIGURE 8. Schematic of Pipeline Pull Method.



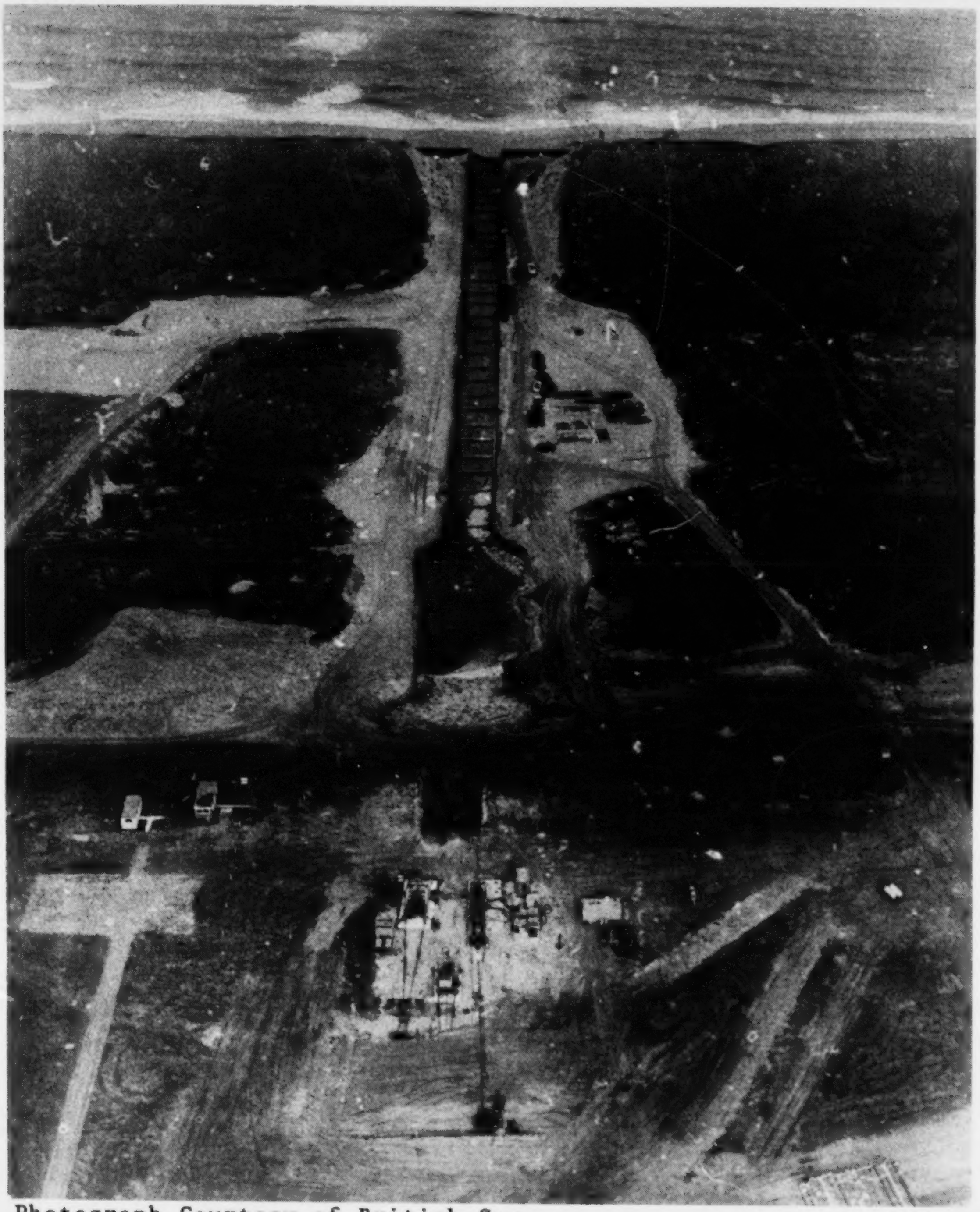
Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 9. Rollers in Pipeline Trench with Pipe Strings in Background.

etc.) may be used to stabilize the core of the dune structure, the final layer being original outer dune material;

- objects such as fences or pine tree tops may be placed in the trench to stabilize the inner structure; and
- dune sand may be mixed with topsoil to later aid in revegetation.

After the trench has been refilled, the dune is often replanted with vegetation similar to the surrounding dunes. Where seasonal conditions do not permit immediate replanting, netting, thatching or fences may be used as anti-erosion devices until revegetation can be completed. Fertilizer is often added to the upper soil layer on the dune to further aid in revegetation.



Photograph Courtesy of British Gas.

FIGURE 10. Typical Set-up of Shore-Based Pull. Winch site is at bottom of photograph.

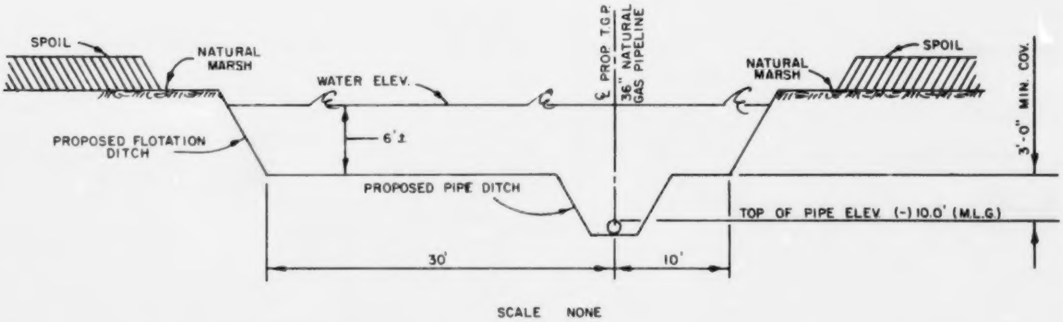
Backdune areas: The trench landward of the dune is refilled with the original material and restored to its original contours. The upper layer is fertilized and the area is replanted. If this backdune area has served as a work site, it is cleaned of debris, graded and replanted. Temporary roads and paths to the work site are removed to the extent possible. The areas are revegetated with native plants. Occasionally, to speed recovery, quick growing annual grasses, such as rye grass, are used to provide a protective vegetative cover while the native vegetation is taking hold. Natural drainage patterns are usually restored to the extent possible to prevent washouts and erosion.

WETLAND INSTALLATION

Two basic methods are used to install pipelines in wetlands: the flotation method, which requires a wide flotation canal for the operation of a small laybarge; and the push or shove method which involves welding a string of pipe, and pushing it through a small, water-filled excavated ditch. The push method is utilized in wetlands with firmer, more stable soil conditions, where a typical, dry land spread can operate. Soft, muddy soils usually necessitate the use of the flotation method.

Flotation Method

Canal Excavations: The flotation method requires a large canal -- the flotation canal -- to be dredged through the wetland to provide access for barge-mounted welding and laying equipment. Barge-mounted bucket dredges first excavate a canal approximately 40 to 50 feet wide and six to eight feet deep (Figure 11). The ditch for the pipe itself is then excavated in the bottom of the canal to place the top of the pipeline some

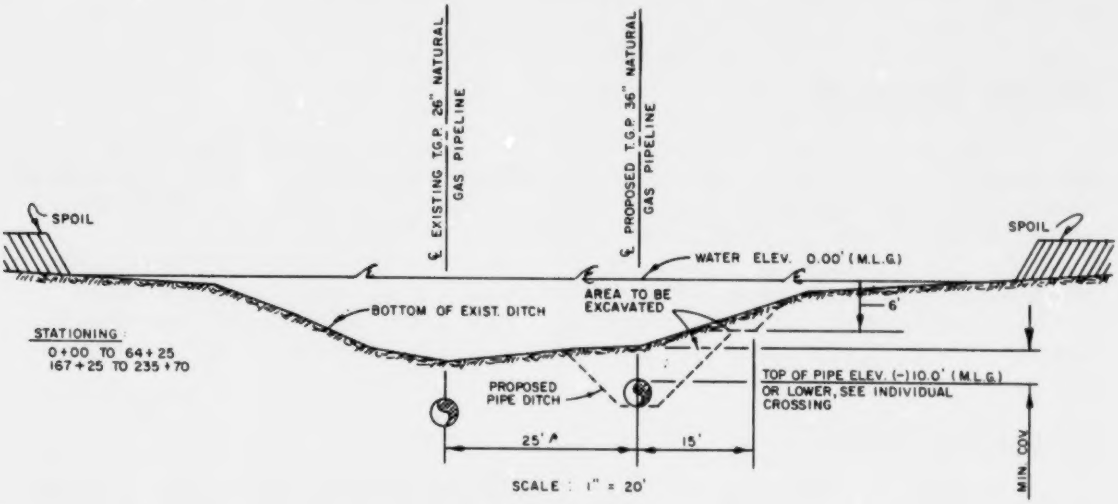


Source: Tennessee Gas Pipeline Co.

FIGURE 11. Profile of a Typical Flotation Canal.

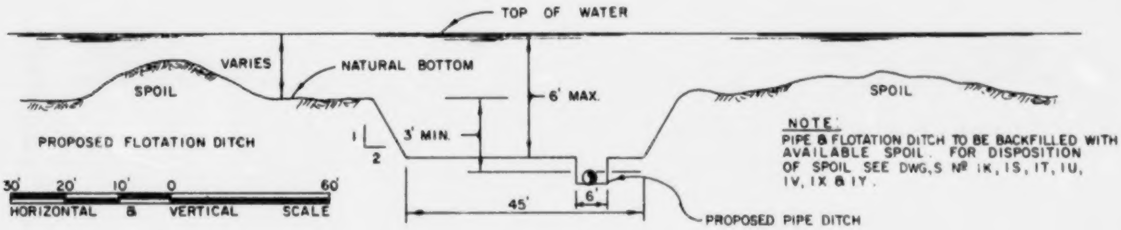
ten to twelve feet below the water surface. The pipe ditch is sometimes excavated slightly off center in the canal, particularly when a side ramp pipeline laybarge is to be used.

In some cases, an existing flotation canal can be used for a second pipeline installation. Figure 12 shows a planned second pipeline ditch to be excavated some 25 feet to one side of an existing pipeline. Flotation canals are also used in places where water depth does not allow operation of laybarges, such as in shallow bays (Figure 13).


SPOIL
℄ EXISTING T.G.P. 26" NATURAL GAS PIPELINE
℄ PROPOSED T.G.P. 36" NATURAL GAS PIPELINE
WATER ELEV. 0.00' (M.L.G.)
SPOIL
BOTTOM OF EXIST. DITCH
AREA TO BE EXCAVATED
6'
STATIONING:
0+00 TO 64+25
167+25 TO 235+70
PROPOSED PIPE DITCH
TOP OF PIPE ELEV. (-)10.0' (M.L.G.) OR LOWER, SEE INDIVIDUAL CROSSING
25'
15'
MIN. COV.
SCALE: 1" = 20'

Source: Tennessee Gas Pipeline Co.

FIGURE 12. Excavation of an Additional Pipe Ditch in an Existing Flotation Canal.

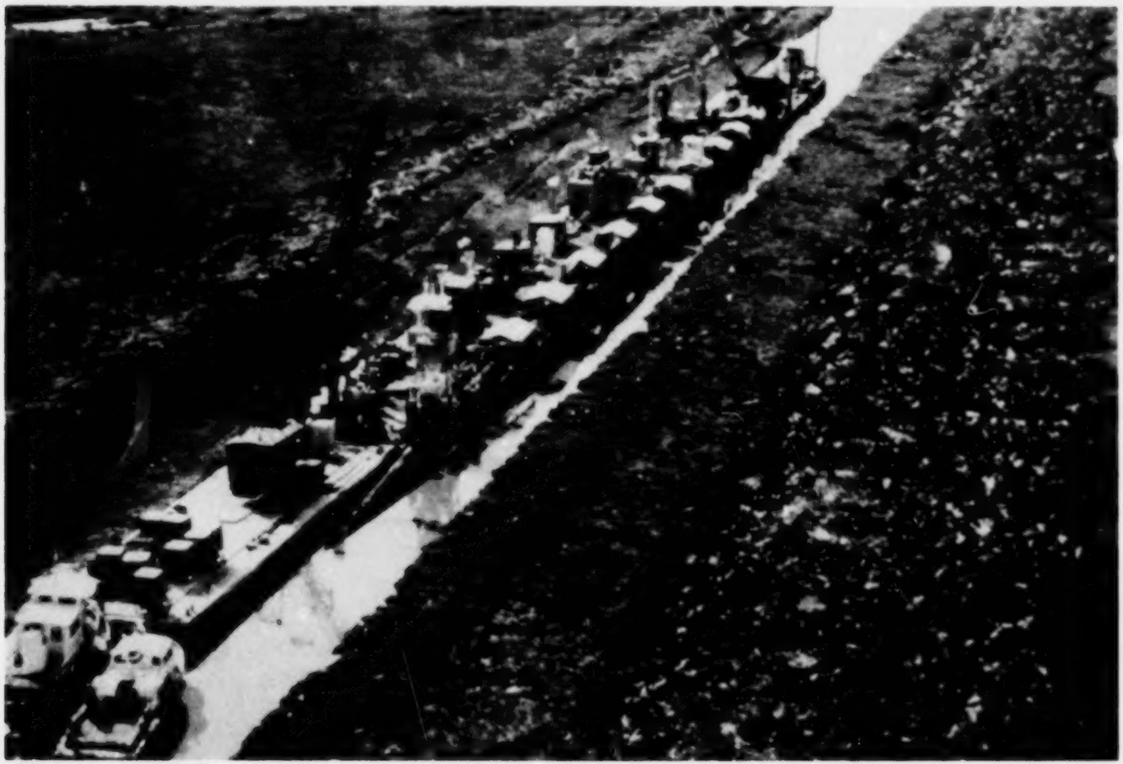

TOP OF WATER
VARIES
NATURAL BOTTOM
SPOIL
6' MAX.
SPOIL
PROPOSED FLOTATION DITCH
1
2
3' MIN.
NOTE:
PIPE & FLOTATION DITCH TO BE BACKFILLED WITH AVAILABLE SPOIL. FOR DISPOSITION OF SPOIL SEE DWG,S Nº IK, IS, IT, IU, IV, IX & IY.
30' 20' 10' 0 60'
HORIZONTAL & VERTICAL SCALE
45'
6'
PROPOSED PIPE DITCH

Source: Tennessee Gas Pipeline Co.

FIGURE 13. Profile of a Flotation Canal in Shallow Open Water.

The highly fluid spoil removed from the canal and ditch is dumped about 30 to 40 feet back from each side of the canal forming a low, flat levee. Levees range from three to five feet in height, and may be as wide as 85 feet at the base, depending on the size of the excavation and the stability of the material removed. The total right-of-way width required for the flotation method is approximately 300 feet (McGinnis et al., 1972).

Pipeline Installation: A laybarge or series of laybarges moves up the flotation canal welding sections of pipe and passing them over the stern into the prepared ditch in the same manner as an offshore laybarge operation (Figure 14). The pipe joints and welds are usually covered with a protective mastic coating for corrosion protection and reinforced concrete to provide negative buoyancy and protection from impacts from boating traffic or anchors.



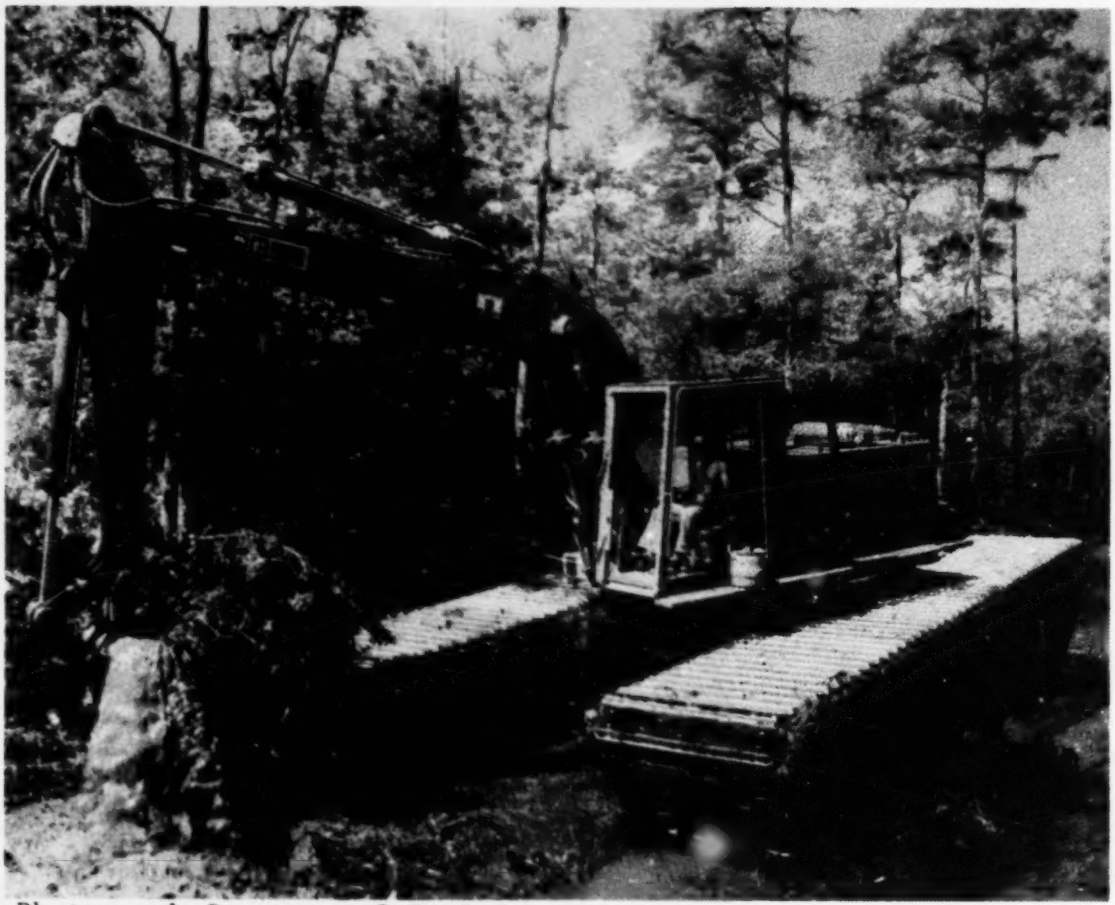
Photograph Courtesy of Pipeline Contractors Association, 1976.

FIGURE 14. Lay Barge Operating in Flotation Canal.

Push Method

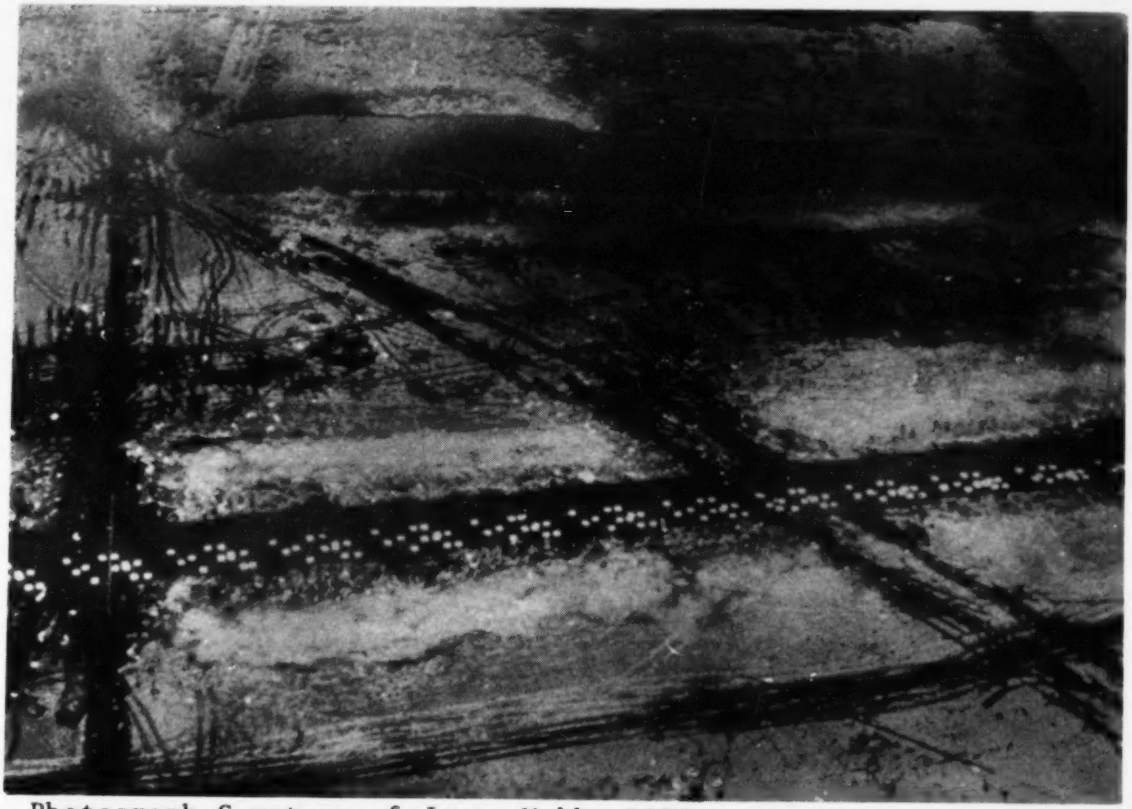
Ditch Excavation: A marsh buggy mounted clamshell or dragline dredge is used to excavate the pipe ditch. The marsh buggy (Figure 15) is an amphibious vehicle with both tractor-like treads and pontoons enabling the vehicle to easily traverse the marsh. One problem with using marsh buggies is the compaction of spongy marsh soil under the treads, which can leave small, canal-like features (Figure 16) on the marsh surface, that occasionally cause alterations in the marsh drainage patterns.

The pipe ditch is generally four to six feet wide and approximately eight feet deep (Figure 17). Spoil is piled on both sides of the ditch to be used for refilling the ditch. Width of the right-of-way for the push method is commonly



Photograph Courtesy of Kori Corporation.

FIGURE 15. Marsh Buggy Excavator.



Photograph Courtesy of James Webb, LOTA.

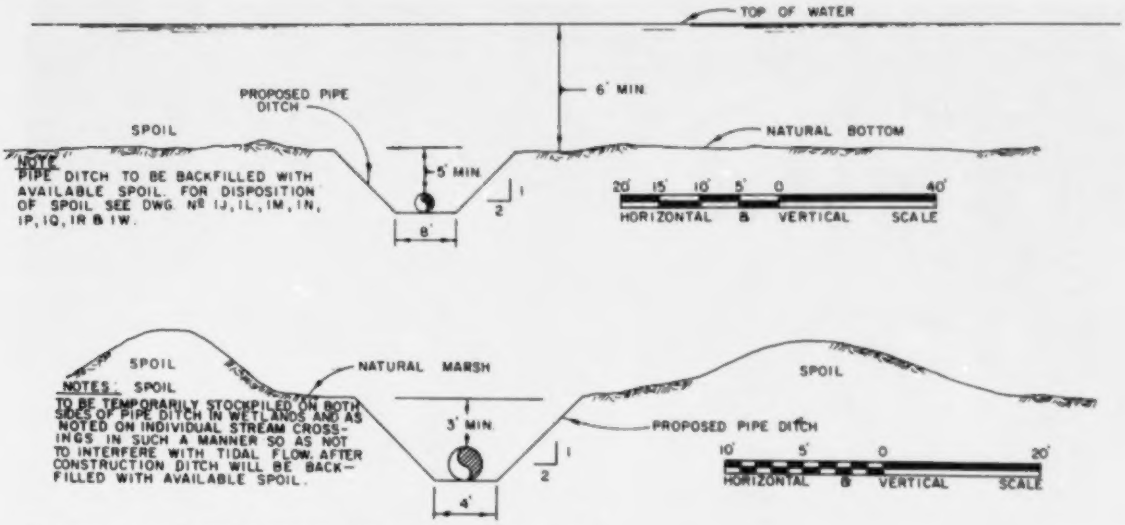
FIGURE 16. Marsh Buggy Tracks in a Wetland.

150 feet (McGinnis et al., 1972).

Pipe Installation: A pipe welding station is set up either on land or on a stationary laybarge (Figure 18). As sections of concrete-coated pipe are welded, floats are strapped to the pipe, and the completed section is slowly pushed into the ditch (Figure 19). After the entire length of pipeline is floated into position (Figure 20), the floats are cut away, and the line is allowed to settle to the bottom of the ditch. The push ditch is usually required to be refilled after pipe installation. Sections of pipeline up to 15 miles long have been installed by the push method.

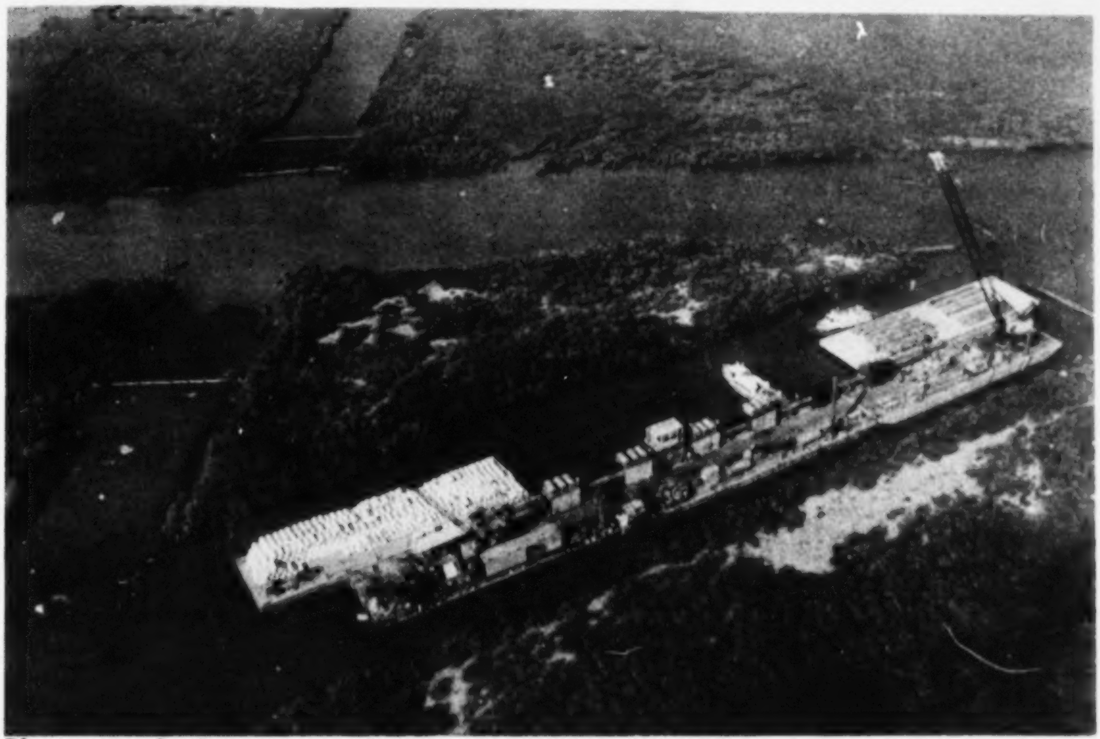
Wetland Restoration

Restorations in wetland systems are usually very difficult, and attempts at restoration are usually associated with strict requirements contained in rights-of-way negotiation or specifications by local or state governmental agencies,


TOP OF WATER
6' MIN.
PROPOSED PIPE DITCH
SPOIL
NATURAL BOTTOM
5' MIN.
NOTE
PIPE DITCH TO BE BACKFILLED WITH AVAILABLE SPOIL. FOR DISPOSITION OF SPOIL SEE DWG. Nº 1J, 1L, 1M, 1N, 1P, 1Q, 1R & 1W.
1
2
8'
20' 15' 10' 5' 0 40'
HORIZONTAL & VERTICAL SCALE
SPOIL
NATURAL MARSH
SPOIL
NOTES: SPOIL
TO BE TEMPORARILY STOCKPILED ON BOTH SIDES OF PIPE DITCH IN WETLANDS AND AS NOTED ON INDIVIDUAL STREAM CROSSINGS IN SUCH A MANNER SO AS NOT TO INTERFERE WITH TIDAL FLOW. AFTER CONSTRUCTION DITCH WILL BE BACK-FILLED WITH AVAILABLE SPOIL.
3' MIN.
PROPOSED PIPE DITCH
1
2
4'
10' 5' 0 20'
HORIZONTAL & VERTICAL SCALE

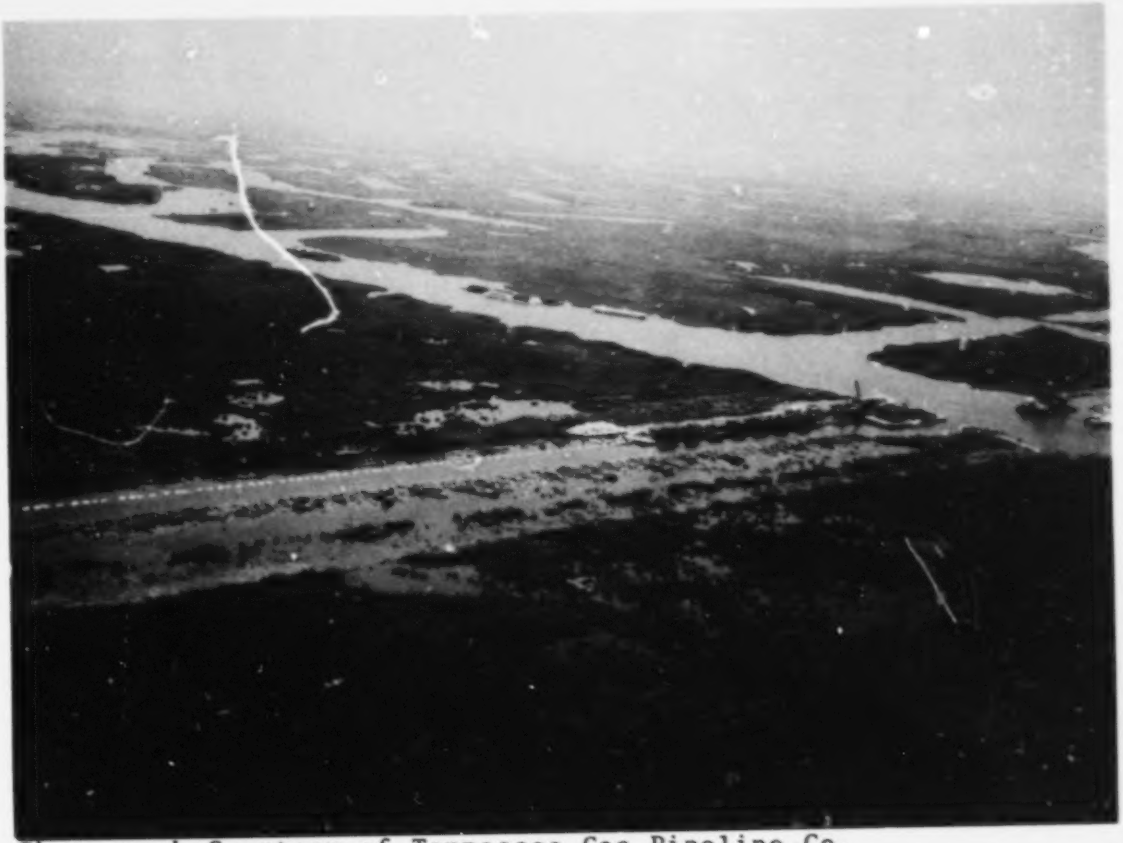
Source: Tennessee Gas Pipeline Co.

FIGURE 17. Profiles of Typical Push Ditches.



Photograph Courtesy of Tennessee Gas Pipeline Co.

FIGURE 18. Stationary Lay Barge Used as a Welding Station for Push Method.

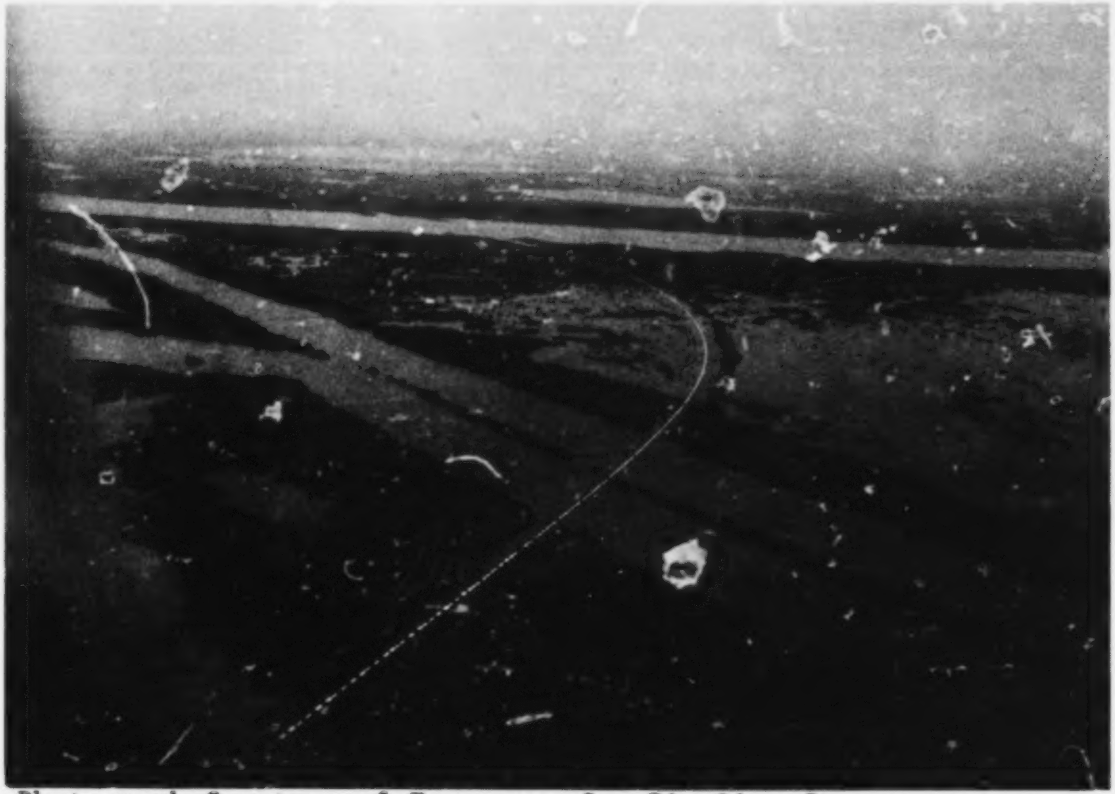


Photograph Courtesy of Tennessee Gas Pipeline Co.

FIGURE 19. Pipeline With Attached Floats Being Pushed Off Laybarge to the Left.

rather than the need to provide additional pipe protection. Even where restoration is attempted, a total return of the aesthetic quality of the system is not expected, and the primary concern is to minimize the impacts of the construction on the environmental system's function.

Generally, there is never enough spoil from a flotation canal excavation to completely refill the canal. Material quantities are reduced due to shrinkage, subsidence, and dispersal over the surface of the marsh. The decision to refill is generally made on a case-by-case basis. The continuous levees of a flotation canal may, however, be required to be breached in several places to prevent alteration of the wetland's natural drainage pattern. Where refilling is required, dredging of additional material from nearby open water or lakes may be necessary (McGinnis et al., 1972.)

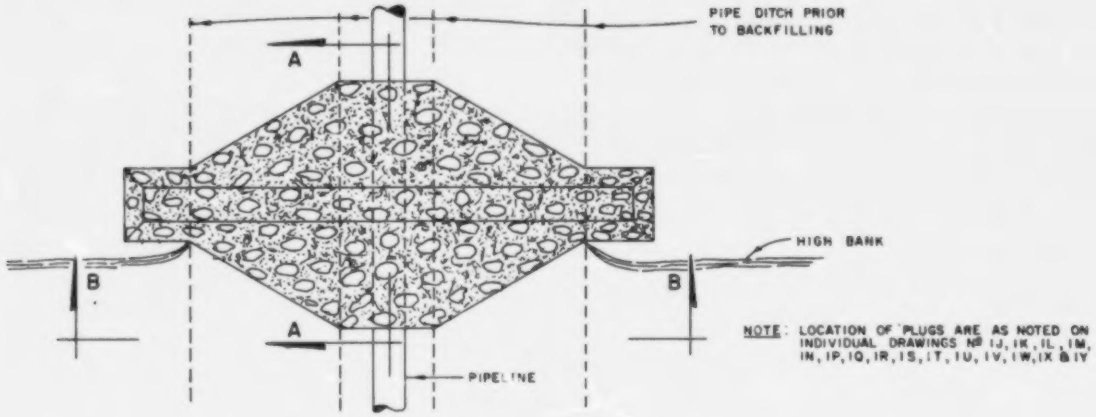


Photograph Courtesy of Tennessee Gas Pipeline Co.

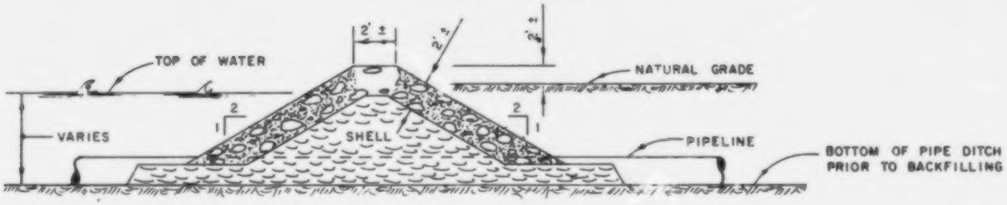
FIGURE 20. Pipeline Floating in Push Ditch. White Objects are Floats.

Push ditches, which are excavated in firmer soil, are easier to restore. The spoil is simply replaced in the ditch, and while shrinkage and subsidence of the spoils may not allow the ditch to be completely refilled, there is usually no canal or open water after completion. In many cases, the regrowth of native vegetation may cover all visual evidence of the ditch (McGinnis et al., 1972).

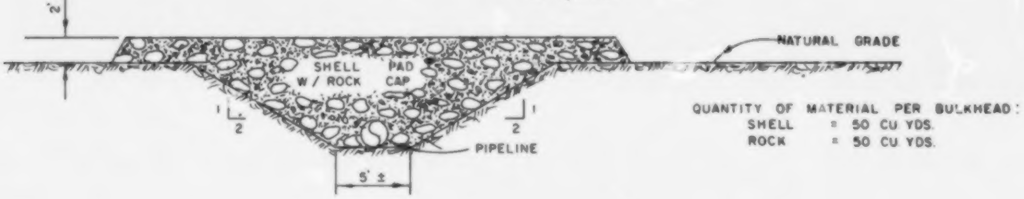
Landowners or government agencies may require flotation canals and push ditches to be blocked by bulkheads, plugs, or dams where they cross major waterways. They are required as a means to restrict boat traffic; the wakes of motorboats can cause extensive erosion of the sides of canals or ditches (McGinnis et al., 1972). Plugs are permanent structures usually made of dense, heavy materials, such as shell, and often have a rock cap (Figure 21). Plugs can also be used to prevent alterations in natural drainage patterns and to prevent the mixing of fresh and salt water. In these situations, plugs may


PIPE DITCH PRIOR TO BACKFILLING
A
A
HIGH BANK
B
B
PIPELINE
NOTE: LOCATION OF PLUGS ARE AS NOTED ON INDIVIDUAL DRAWINGS Nº 1J, 1K, 1L, 1M, 1N, 1P, 1Q, 1R, 1S, 1T, 1U, 1V, 1W, 1X & 1Y

PLAN VIEW
NO SCALE


2' ±
2' ±
2' ±
TOP OF WATER
NATURAL GRADE
VARIES
2
1
SHELL
2
1
PIPELINE
BOTTOM OF PIPE DITCH PRIOR TO BACKFILLING

SECTION A – A
NO SCALE


2' ±
NATURAL GRADE
SHELL PAD W/ROCK CAP
1
2
1
2
PIPELINE
5' ±
QUANTITY OF MATERIAL PER BULKHEAD:
SHELL = 50 CU. YDS.
ROCK = 50 CU. YDS.

SECTION B – B
NO SCALE

Source: Tennessee Gas Pipeline Co.

FIGURE 21. Plug Used in Some Wetland Installations.

also contain impervious materials (e.g., clay).

Revegetation is not commonly attempted in wetland restorations. A distinct community of emergent vegetation, made up of brush and trees, is usually seen on the levees and spoil piles in contrast to the predominance of marsh grasses on the undisturbed wetland (Figure 22).

NERBC Photograph.

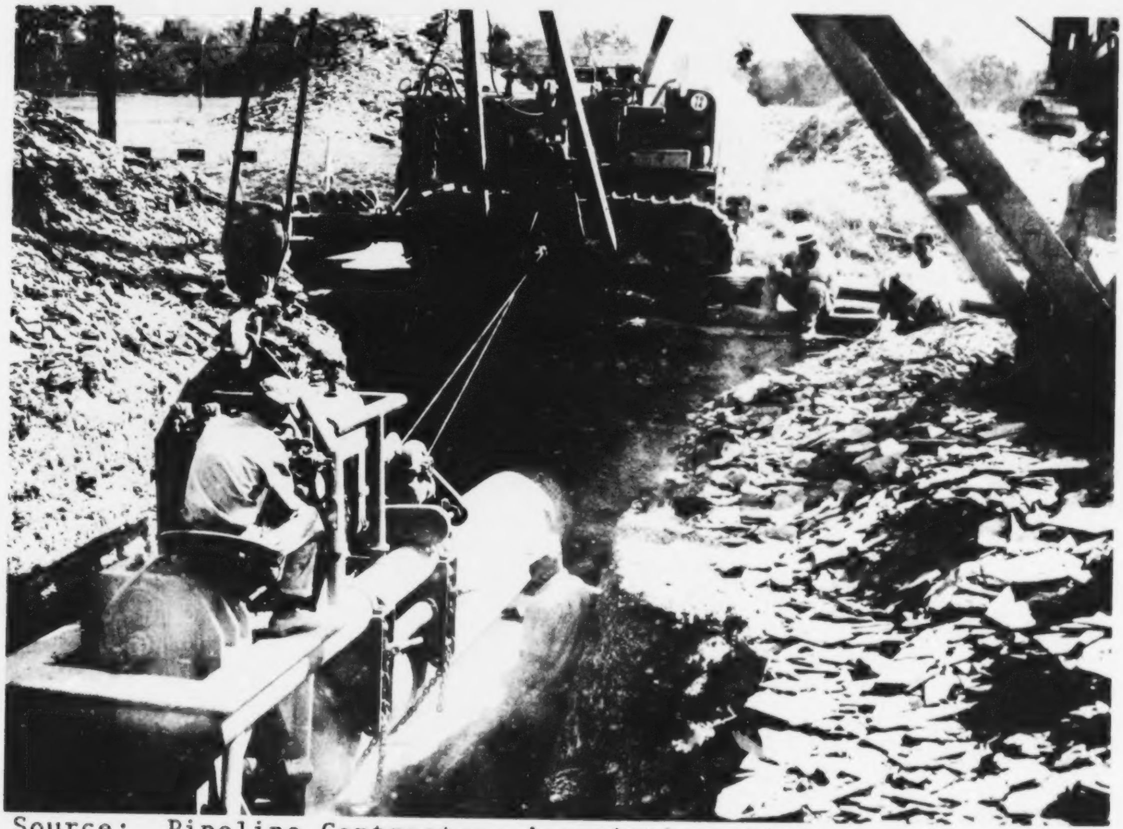
FIGURE 22. Trees and Shrubs Growing on Levees Along Flotation Canals.

SPECIAL INSTALLATION TECHNIQUES

Highway and Railroad Crossings

Two methods are generally used to install pipelines under highways and railroad tracks: boring under the tracks or highway; or construction of a temporary bridge over a standard pipe excavation.

Railroad and highway crossings are usually accomplished by boring under the surface, a procedure which does not disturb the normal traffic flow overhead. An auger-type bit is used to bore a horizontal hole (Figure 23) which is then lined with a steel casing. The dimensions of the tunnel and the casing are chosen to provide a secure fit for the pipeline, which is either pushed or pulled through the encased tunnel. Where rock or rubble obstructs normal boring operations, carefully placed explosives or jackhammers and pavement breakers may be used to clear the obstruction.



Source: Pipeline Contractors Association, 1976.

FIGURE 23. A Road-Boring Machine Drilling Under a Highway.

A temporary bridge (Figure 24) over a pipeline trench is used where roads or tracks are regularly used and where traffic is not easily detoured. Bridges may also be used when the pipe trench must remain open for a long period of time (e.g., as occurred at the Menai Straits, Wales pull operation described in Chapter 4). Following pipeline installation, the bridge is removed, the trench refilled and the roads or tracks replaced. Where a road is very lightly used, the road may be simply cut

Photograph Courtesy of William Binger, LOOP, Inc.

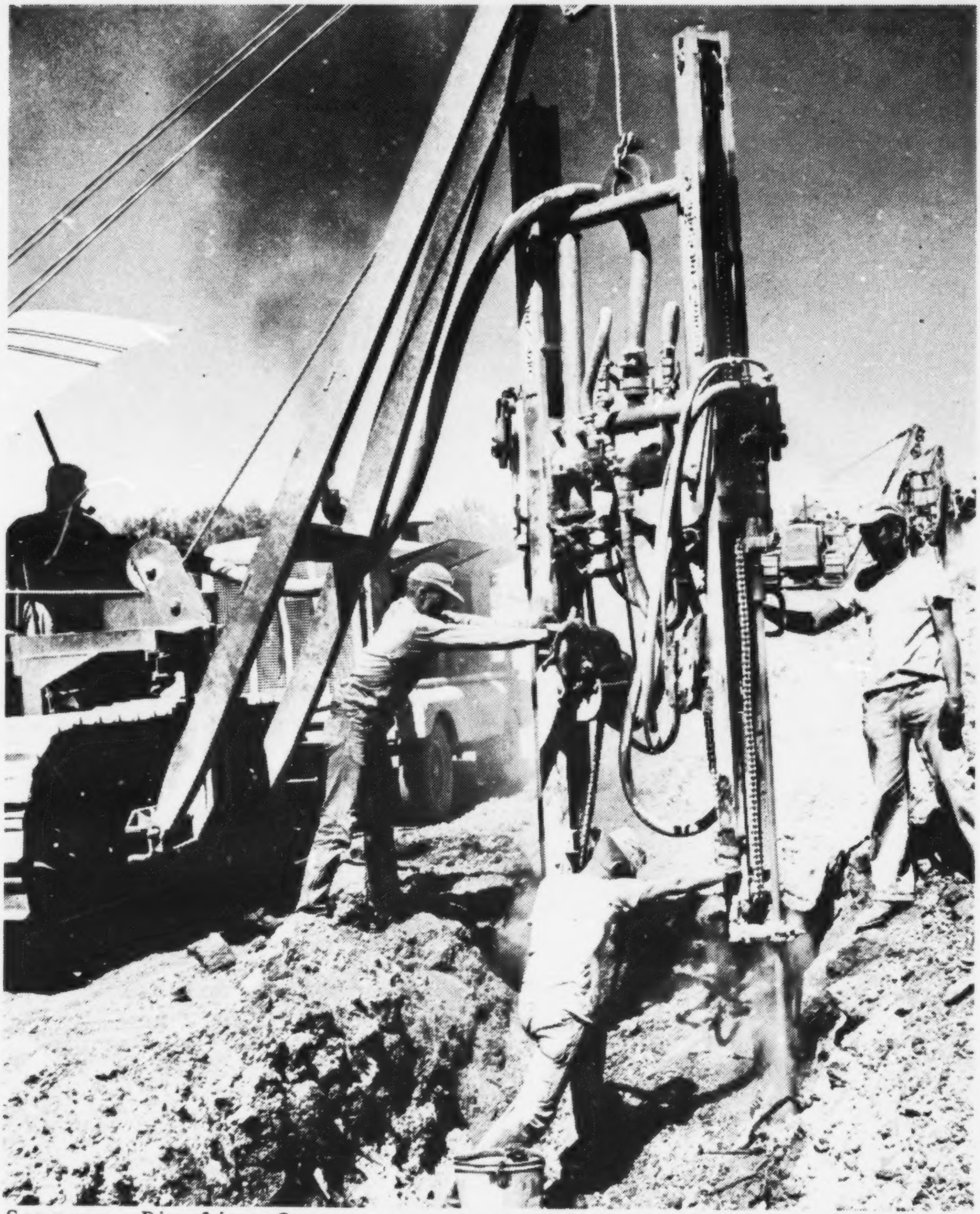
FIGURE 24. Temporary Bridge Over Pipe Trench, Menai Straits, Wales.

open, and the traffic detoured during working hours. At the end of the day, steel plates are placed over the trench to allow traffic to pass.

Rock Blasting

Where rock cannot be loosened using dredges, backhoes, or rippers (a special plow attachment pulled by a large bulldozer), blasting is necessary to prepare the pipeline trench. Onshore, compressed air drills (Figure 25) are used to bore holes in the rock and dynamite charges are placed in the holes. After blasting, the rubble is removed using backhoes.

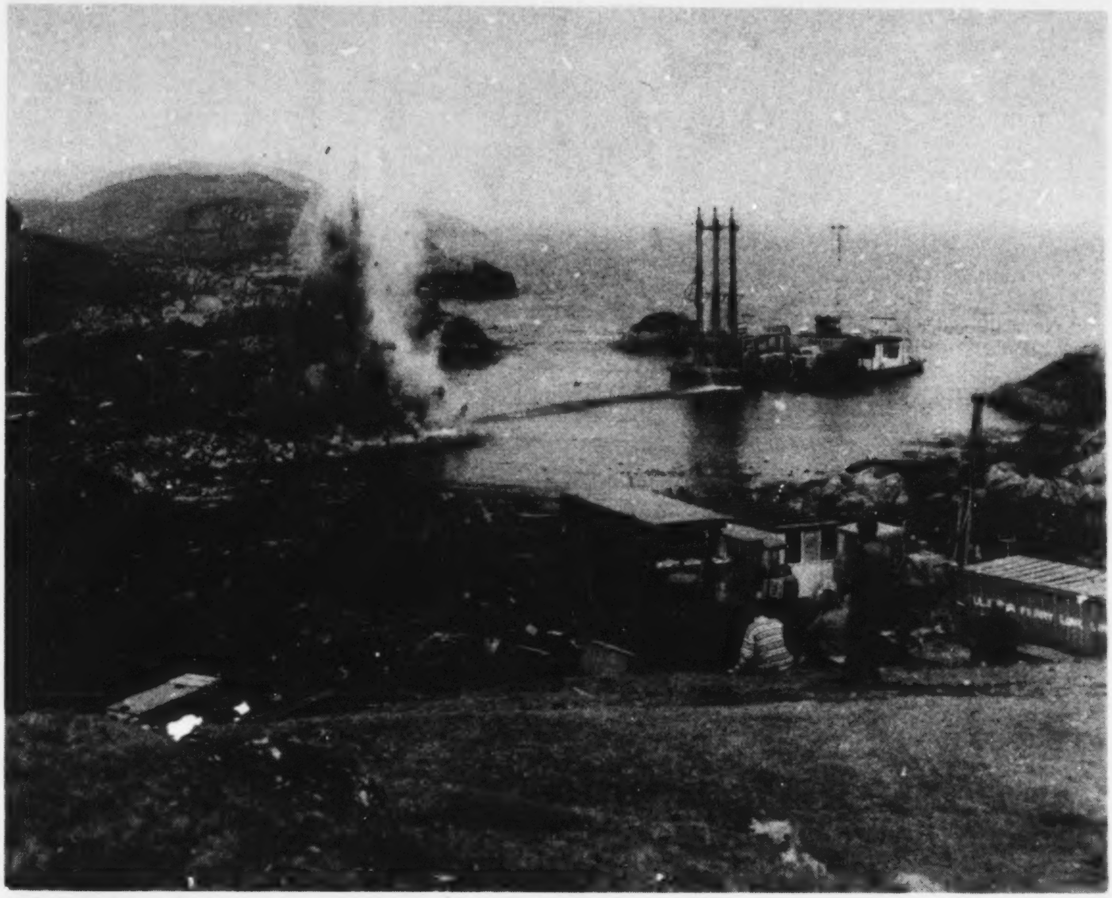
Offshore, rock drills are either barge or pontoon mounted (Figure 26). Divers are often used to supervise drilling and the placement of explosive charges. Barge-mounted dredges (draglines or clamshells) or dipper dredges are used to clean the trench of blasted rock (Figure 27). Sometimes, it may be



Source: Pipeline Contractors Association, 1976.

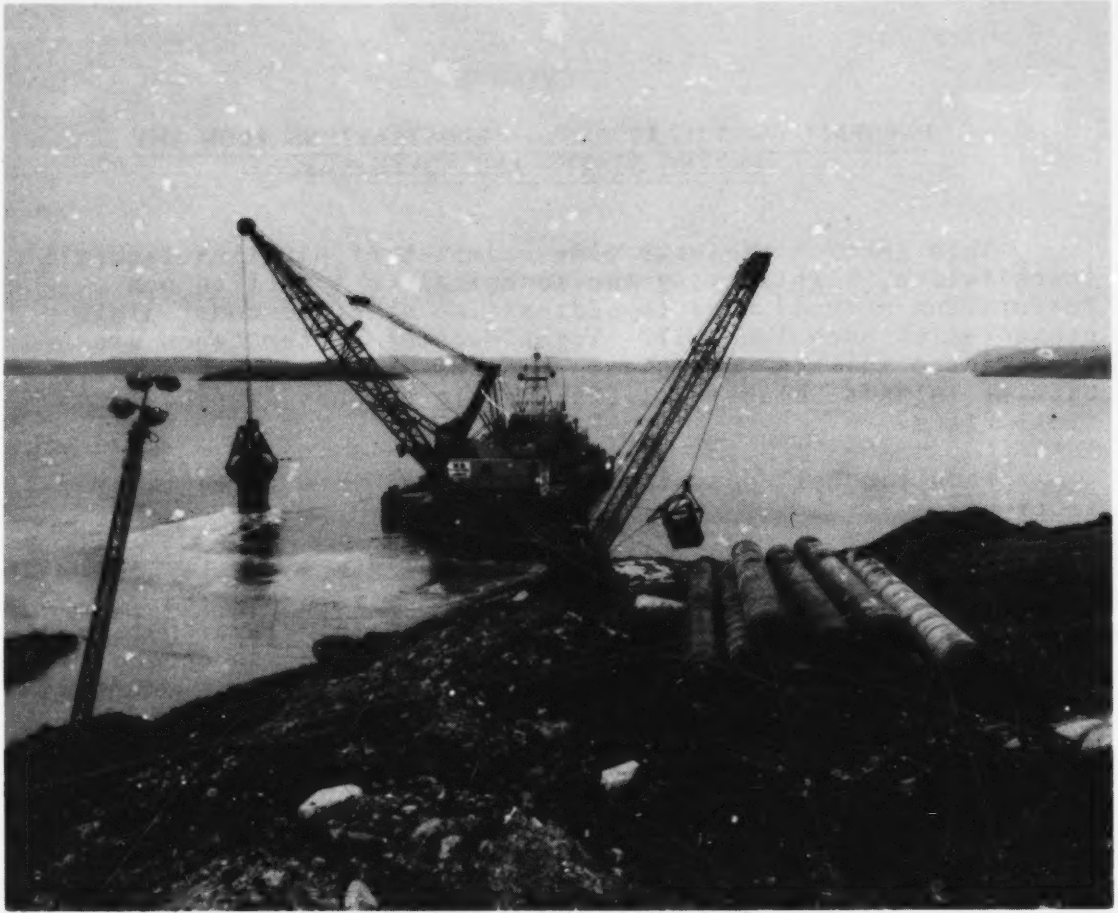
FIGURE 25. Compressed Air Drill Preparing Holes for Explosives.

necessary to use sand or gravel to provide a smooth level surface on the bottom of the trench before the pipe is laid.



Photograph Courtesy of Land and Marine, Ltd.

FIGURE 26. Pontoon Mounted Rock Drills with Blasting in Progress--Grut Wick, Shetland Islands.



Photograph Courtesy of Land and Marine, Ltd.

FIGURE 27. Barge-Mounted Bucket Dredge and Land-Based Dragline Dredge Clearing Trench of Blasted Rock.

SECTION 4

LANDFALL INSTALLATIONS: ILLUSTRATIONS FROM THE UNITED STATES AND NORTH SEA

This section presents nine examples of pipeline landfall installation, highlighting the technical construction and restoration methods used to address the specific constraints presented at each landfall. Eight coastal system types are represented in these examples: beaches, beaches with dunes, barrier islands, bluffs, cliffs, cobble beaches, marshes and tidal flats.

Each landfall description is divided into three major sections:

- *The Setting* -- This section describes the landfall site before installation. The site's physical, biological and use constraints to pipeline installation are highlighted. How the site was chosen is also discussed.
- *Installation* -- This section provides the technical details of the installation. These include: pipeline specifications (diameter, coating, distance from field to shoreline), year and season of installation, construction methods used, and length of time required for installation.
- *Restoration* -- This section describes pre-installation surveys undertaken, restoration techniques used and the success of restoration.

LONG BEACH, NEW YORK* (recreational beach)

Long Beach (Long Island), New York is the site of the eastern landfall for a Transco 26" diameter natural gas pipeline, a 34 mile underwater line connecting New Jersey and Long

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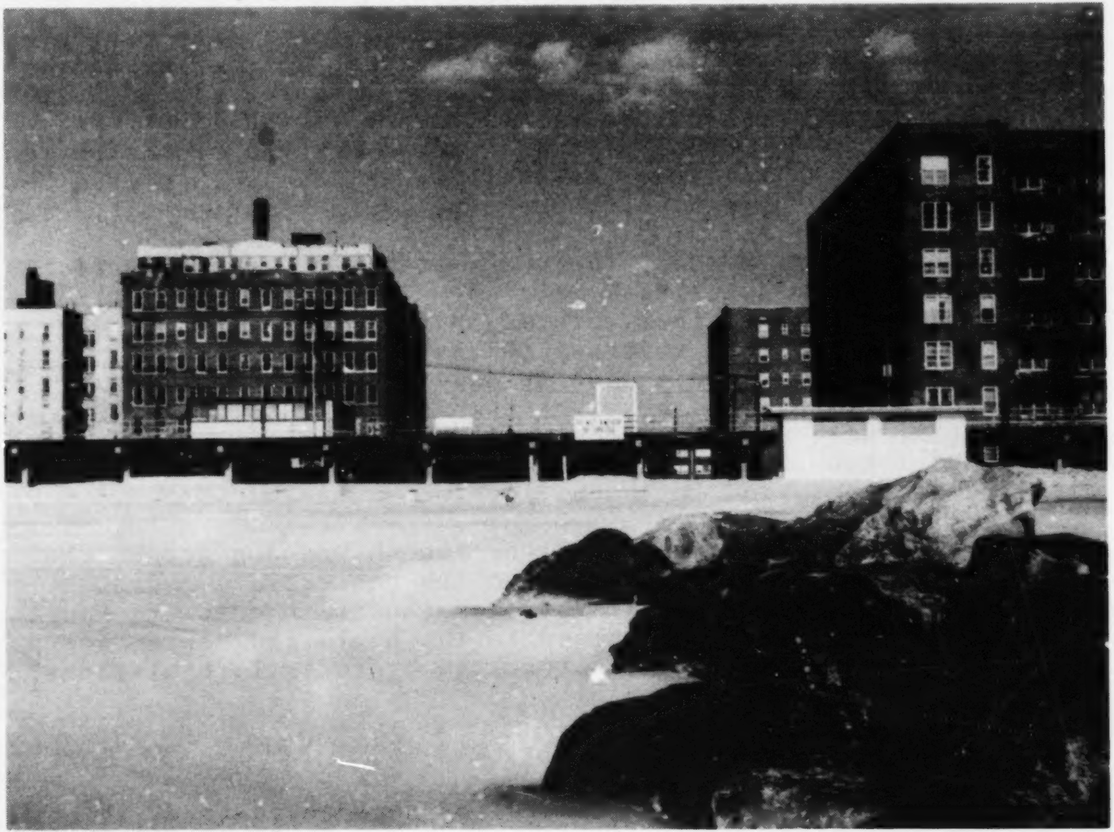
* Primary sources of information: Fletcher Hartley (Transco Pipeline Company) 1979: personal communication, and *Pipeline News*, "Transco Lays World's Longest Pipeline Bay Crossing," Nov. 1967.

Island. (The other landfall at Morgan, New Jersey is also discussed in Section Four.) Installation of the pipeline at Long Beach occurred in September 1967.

The Setting

Long Beach is a sandy, heavily-used recreational beach on the southern shore of Long Island, about fifteen miles from Manhattan. The beach is approximately 200 feet deep and gently slopes from a boardwalk to the waterline. Numerous jetties of irregular boulders (riprap) are present in the surf zone. The beach and boardwalk are shown in Figure 28. Landward, a four-lane boulevard with grassed median strip deadends at the boardwalk.

The physical conditions of the area -- sand, gentle slope, and no vegetation or dunes -- made it a technically ideal landfall for pipeline installation and restoration. Its



NERBC Photograph.

FIGURE 28. Long Beach, Long Island, November 1979. (Line indicates approximate pipeline location.)

recreational use, however, posed a potential use and construction scheduling conflict. Additionally, the underwater route crossed three major navigational channels -- the Raritan Bay Channel (Raritan Bay, New Jersey) and the Swash and Ambrose Channels which provide deepwater entry to the Hudson River. Despite these contraints, the underwater bay crossing was preferred to an overland route through the heavily populated New York/New Jersey metropolitan area, where construction costs are among the highest in the country.

Installation

Construction at the Long Beach landfall began by driving sheet pile into the beach sand to form a cofferdam and retaining structure approximately 20 feet wide and extending into the surf zone about 150 feet. Cranes were run out on top of the cofferdam to excavate a trench about 10 feet deep. Figures 29 and 30 show this installation activity. From the end of the cofferdam to a point approximately 1500 feet offshore, barge-mounted dredges were used to excavate the trench. Pipe joints (which had been precoated with 5/8" of mastic asphaltic coating and 9/16" of reinforced concrete) were welded onshore, placed in the predug trench and pushed through the trench to the 1500 foot point offshore. There the pipe was picked up by a pipelay barge and tied in to the remainder of the line which was laid from New Jersey using conventional offshore pipelaying techniques.*

After laying, most of the underwater line from 1500 feet offshore was trenched using a jetsled. The trench was jetted to a depth of about seven feet, providing five feet of cover over the pipeline. However, to cross the navigation channels, barge-mounted dredges were used to dig the pipeline trench. Three dredges (supported by eight dump scows, two tugboats and two tenders) were used to dredge a total length of 10,600 feet across the three channels. Fifteen to 22 feet of cover over the pipeline were required in the navigation channels.

Landward of the surf zone, the trench was dug across the beach, under the boardwalk, and down the boulevard's median strip using standard land excavation methods. A concrete vault for valve operators was installed in the boulevard median strip adjacent to the boardwalk. As required by federal regulations, vents were installed (Figure 31).

Restoration

At the landfall, after removal of some segments of sheet pile, the trench was refilled with excavated land

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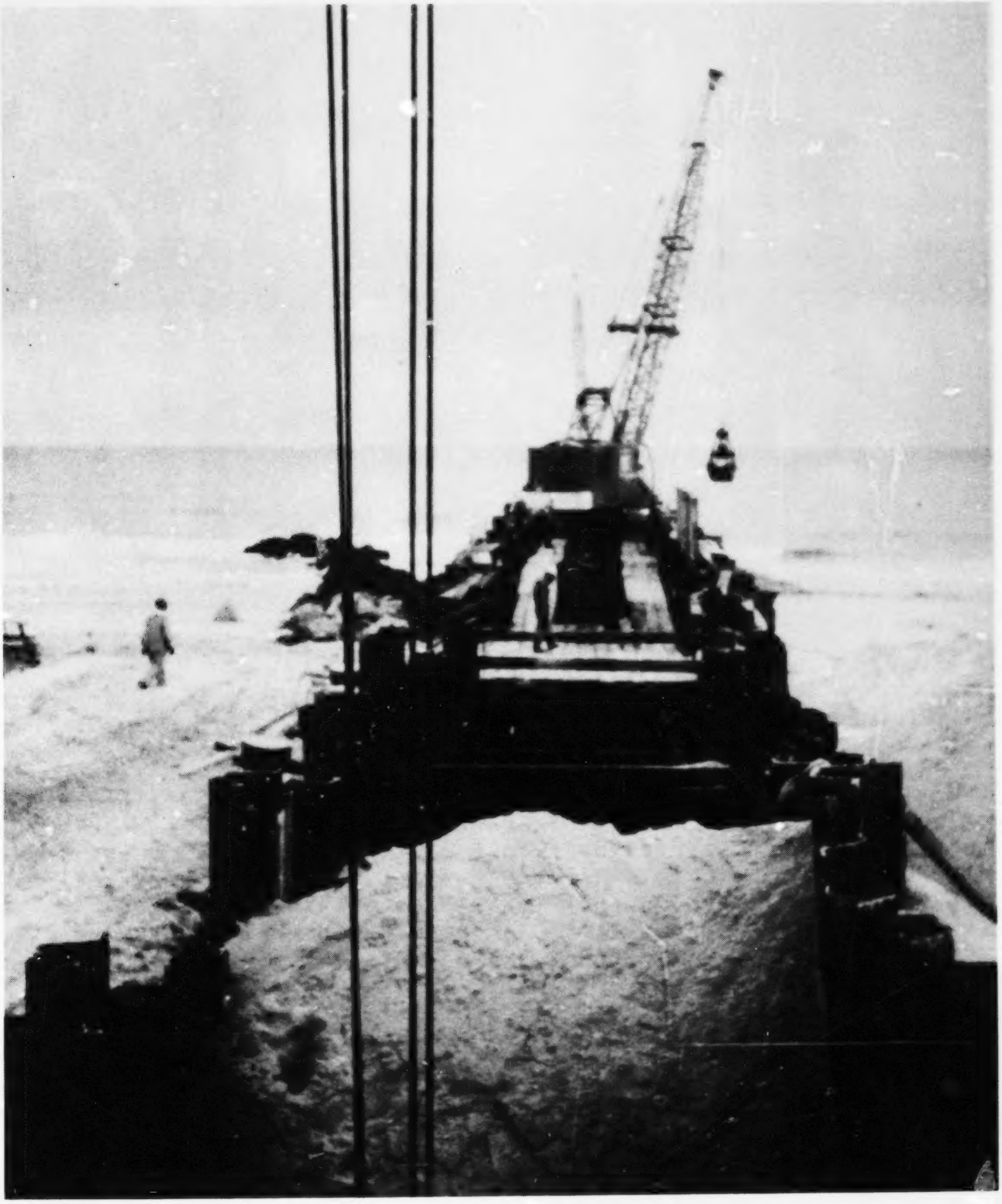
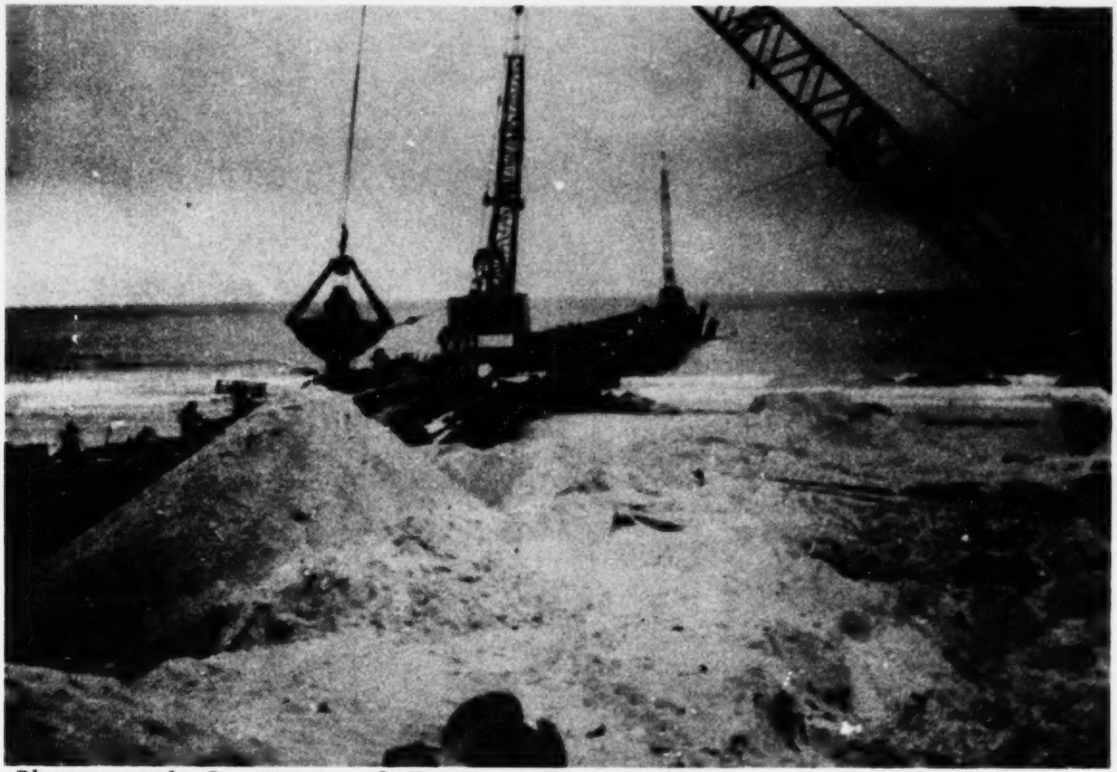
* For further information on offshore pipelaying techniques, see NERBC, 1980, pp. 16-21.



Photograph Courtesy of Transco Pipeline Co.

FIGURE 29. Cofferdam for Trench Excavation, September 1967.

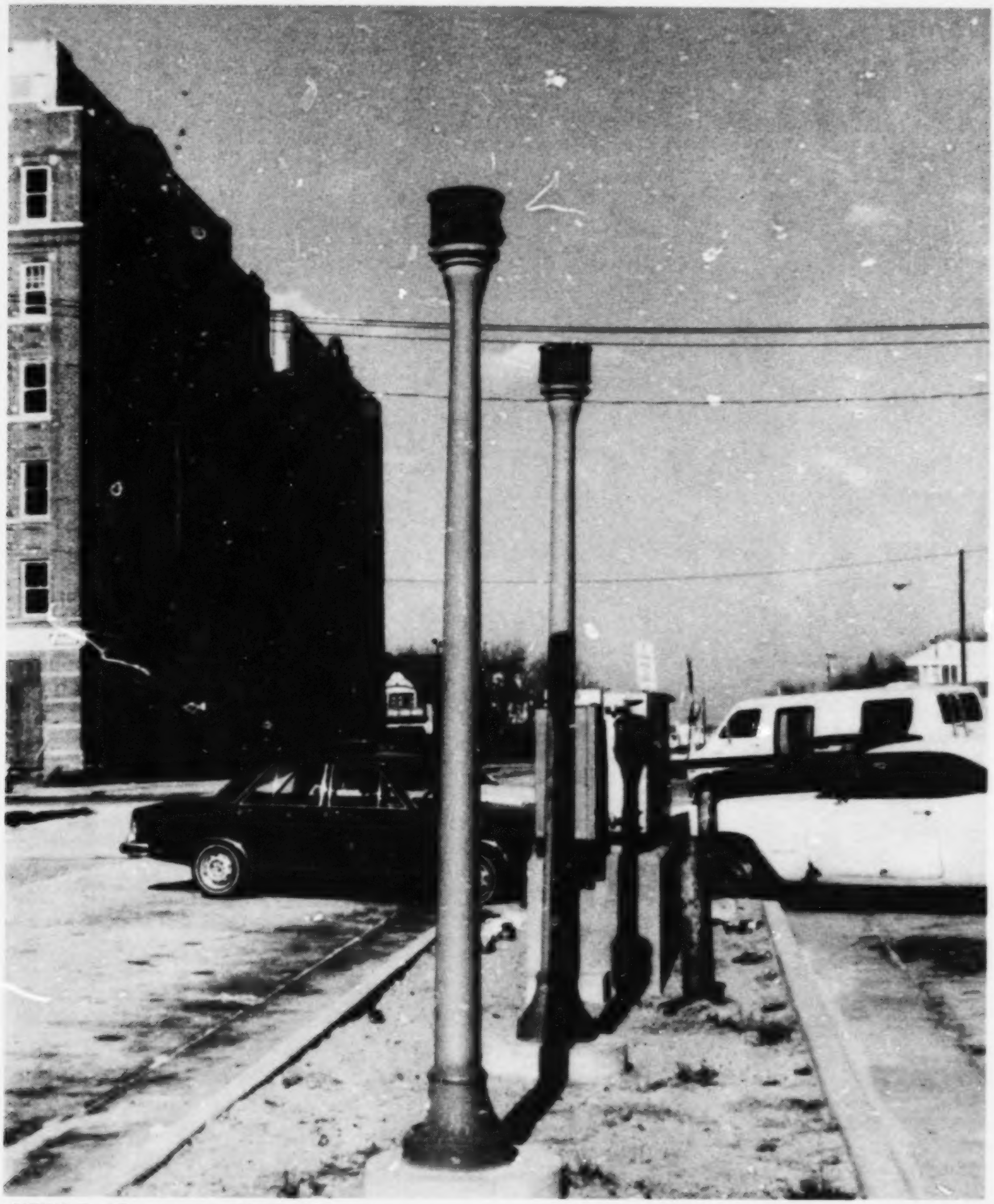


Photograph Courtesy of Transco Pipeline Co.

FIGURE 30. Excavating the Pipeline Trench, September 1967.

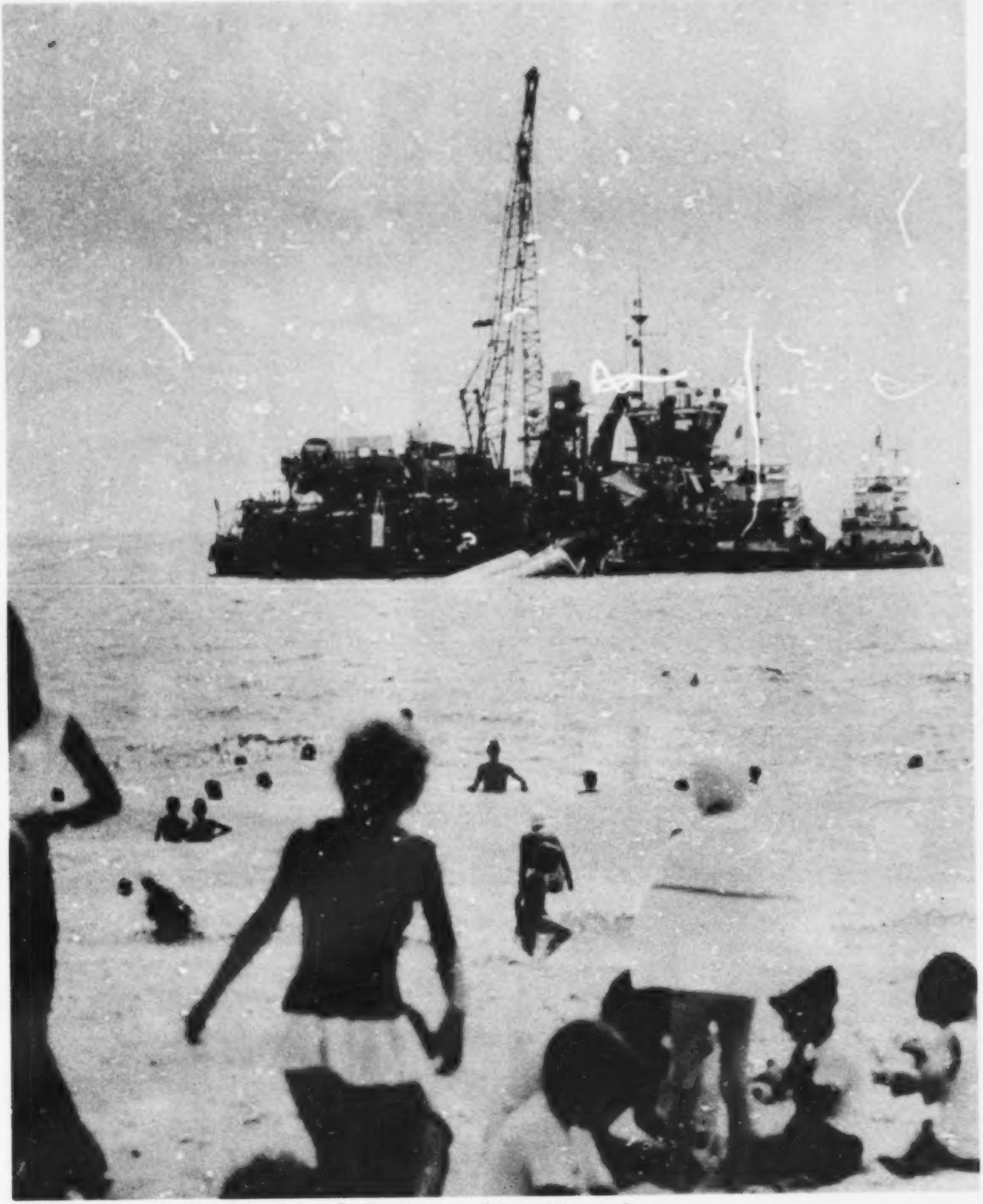
(providing cover of approximately eight feet over the line) and original topography restored. Beach restoration was completed in time for recreational use the following summer, as shown in Figures 32 and 33. To minimize conflicts with this use, the City of Long Beach requested offseason construction which resulted in the scheduling of a September installation. The entire installation -- including restoration -- occurred in about five months, from July through November 1967.

The site was visited in November 1979, 12 years after installation. As Figure 34 illustrates, with the exception of the uncovering of a previously buried wooden jetty, the landfall area remains virtually unchanged and indistinguishable from its surroundings.



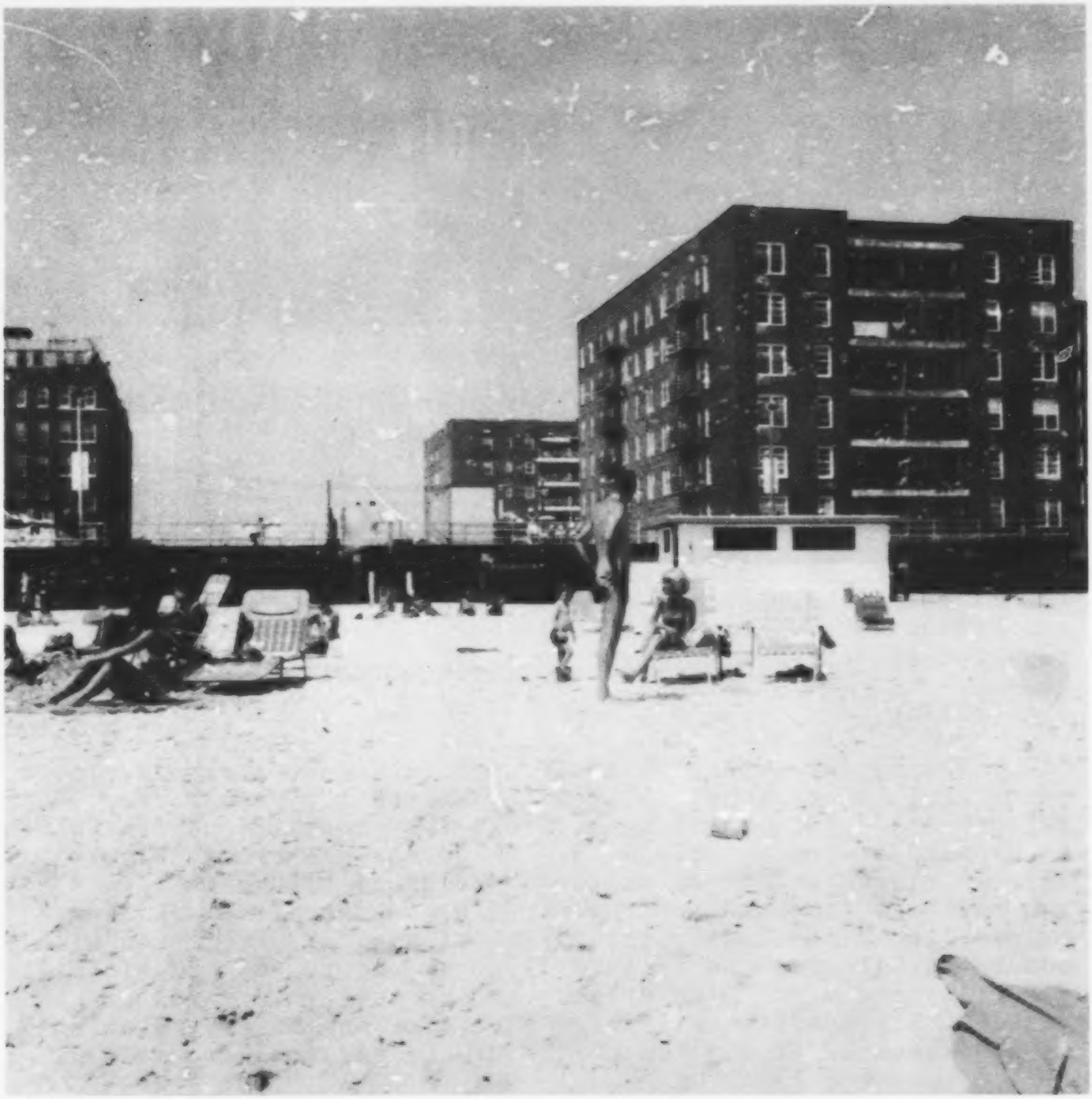
NERBC Photograph.

FIGURE 31. Two Vents for Underground Concrete Vault, November 1979. (Pipeline is under median strip.)



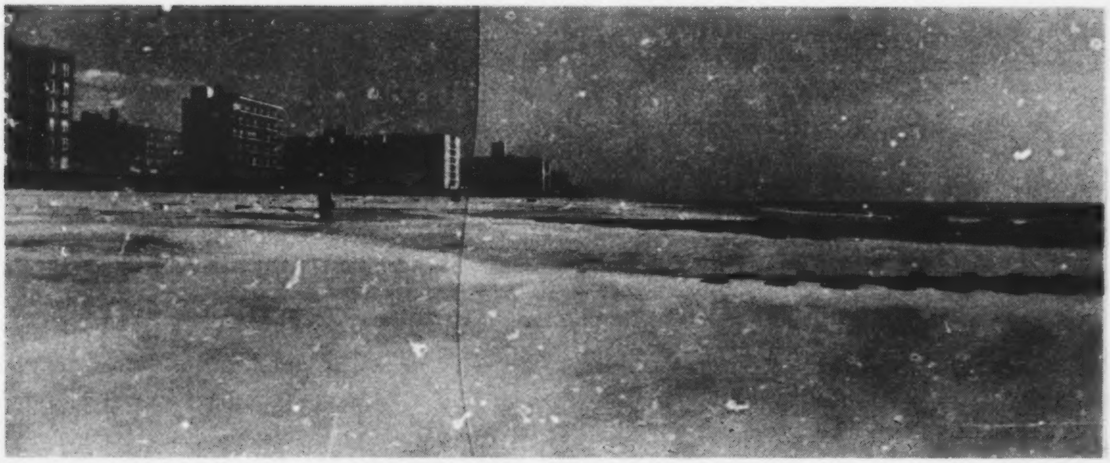
Photograph Courtesy of Transco Pipeline Co.

FIGURE 32. The Landfall and Pipeline Laybarge, Summer 1968.



Photograph Courtesy of Transco Pipeline Co.

FIGURE 33. The Landfall - Summer 1968. (Line indicates approximate pipeline location.)



Photograph Courtesy of Transco Pipeline Co.

FIGURE 34. The Landfall - November 1979. (Line indicates approximate pipeline location.)

MORGAN, NEW JERSEY* (developed area; bluff; railroad tracks)

Morgan, New Jersey is the site of the western landfall for the 34-mile long, 26-inch diameter Transco underwater pipeline connecting New Jersey and Long Island. Installation of the pipeline at Morgan took place in early fall 1967.

The Setting

The Morgan landfall is situated in a moderately developed commercial and residential area on Raritan Bay, New Jersey (Figure 35). The shoreline is fronted by a small mud flat which is exposed at low water and has no appreciable beach (Figure 36). A riprap revetment protects the shore's edge (Figure 37) and railroad tracks which run parallel to shoreline. Landward of the tracks is a small, grassy bluff about 20 feet high with a moderately steep slope (Figure 38). At the top of the bluff is a four-lane divided highway and various commercial and residental properties. Transco's valving and pigging station** is also located at the top of the bluff (Figure 39).

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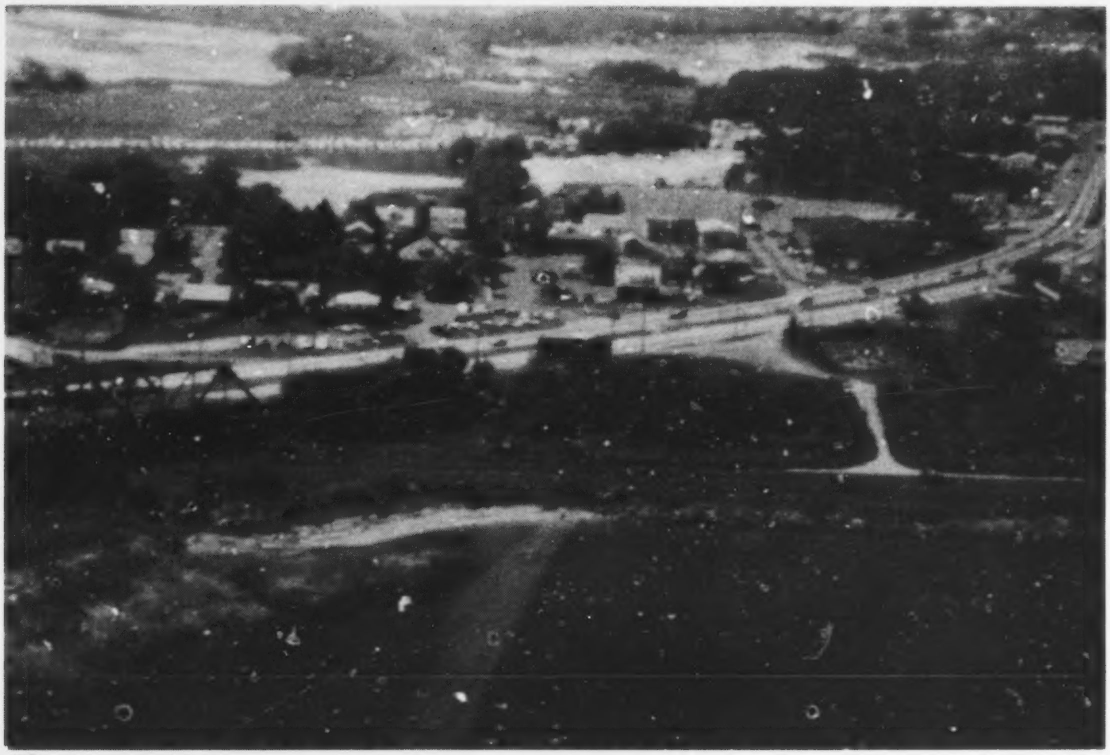
* Primary sources of information: Fletcher Hartley, (Transco Pipeline Company, Houston, Texas) 1979: personal communication; and Pipeline News, November 1967.

** A pig is a bullet-shaped object that is passed through a pipeline to clean the inside of the line or remove obstructions. A pigging station is the location where pigs are placed into or removed from the pipeline system.



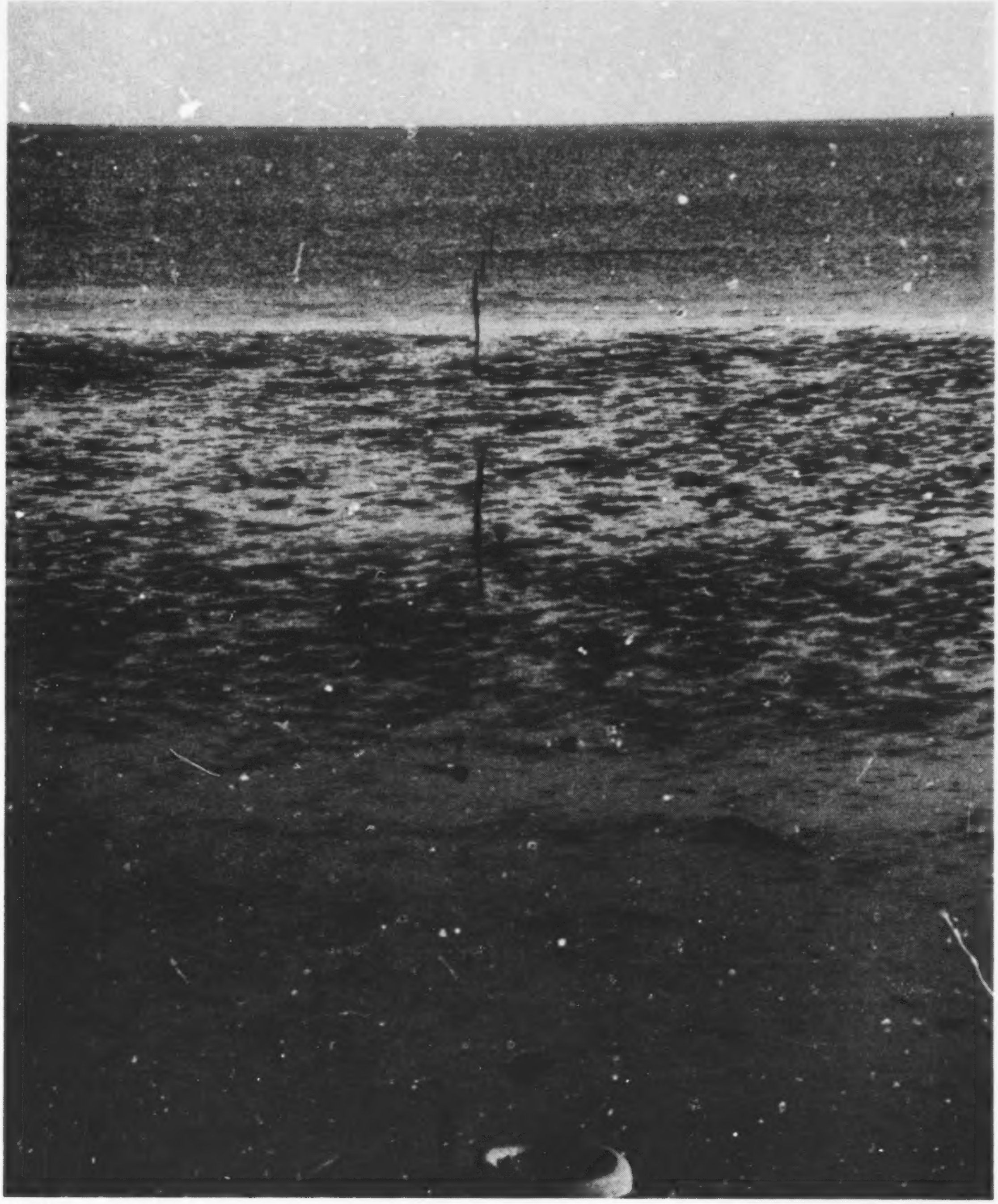
Photograph Courtesy of Transco Pipeline Co.

FIGURE 35. An aerial view of the Morgan, N.J. landfall site after construction - August 1978. Note the valve site adjacent to the highway (right, center).

The commercial and residential development at the landfall, as well as the existence of an operating railroad and the small bluff, presented some potential constraints to the area's use as a landfall. Again, as was the case of the Long Beach landfall, the extreme costs of an overland pipeline through the New York City area was a major factor in choosing the underwater route for the pipeline.

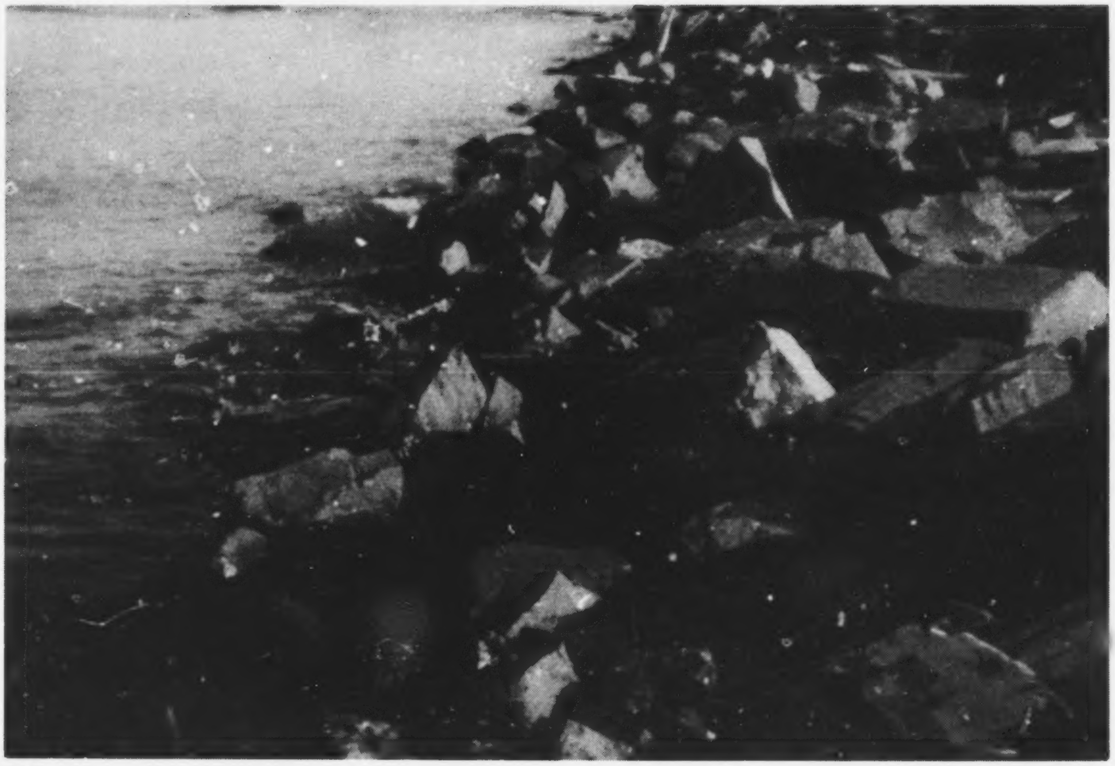
Installation

Initially, the revetment at the edge of the shore was removed. A trench was then dug from the waterline to the railroad track and landward of it to the top of the small bluff using conventional land excavation methods. To cross the track, a tunnel was bored and reinforced with a wooden retainer. About 3500 feet of 26-inch diameter pipe was welded offshore on the laybarge and pulled ashore by winch. From the landfall to approximately 17,000 feet offshore, barge-mounted dredges were



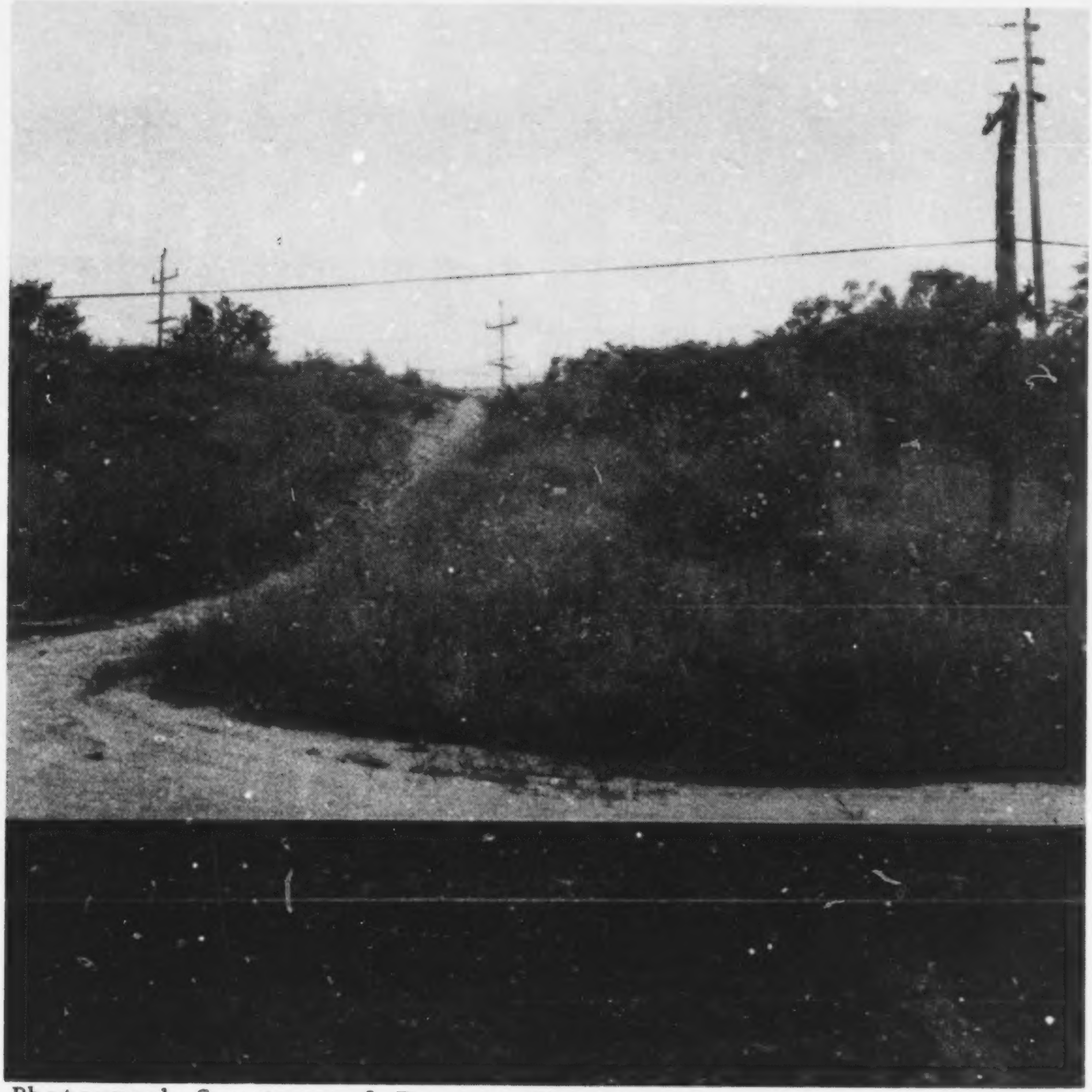
NERBC Photograph.

FIGURE 36. Mudflats along the shore in Raritan Bay at the landfall. The pipeline is located under the line of posts.



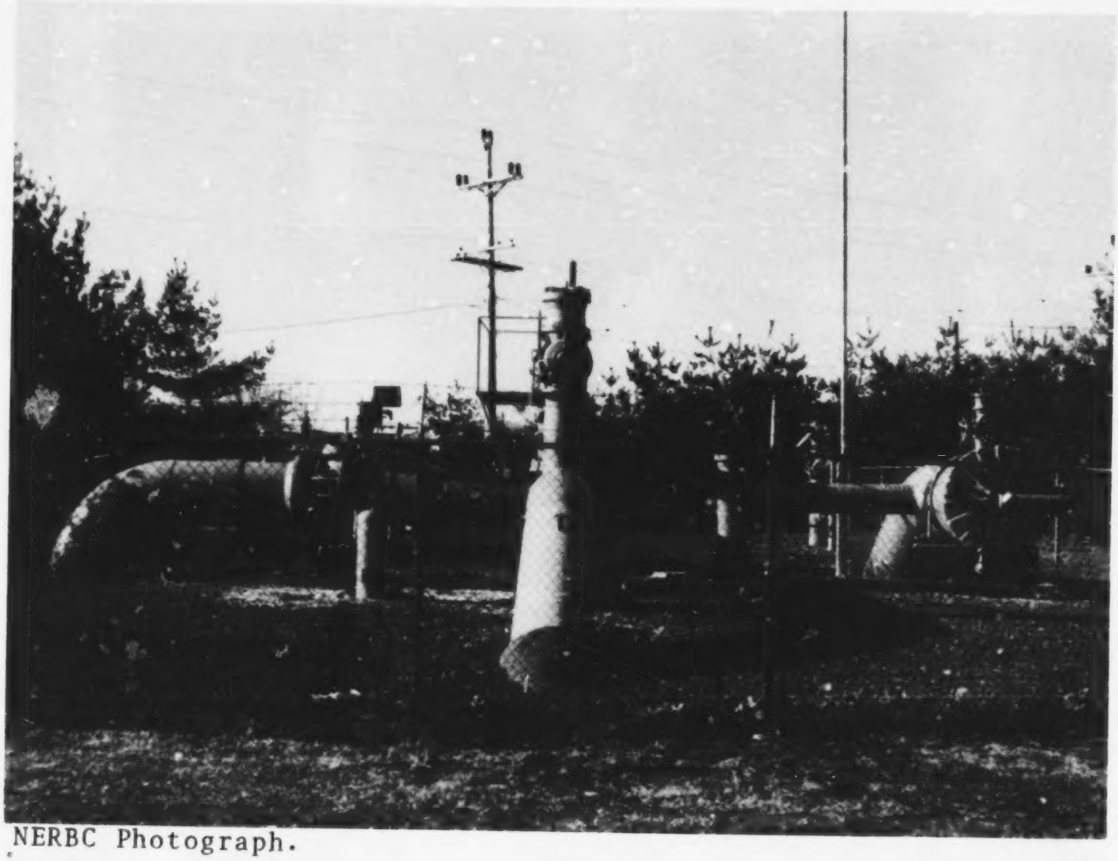
Photograph Courtesy of Transco Pipeline Co.

FIGURE 37. Stone Revetment Protecting the Shoreline at the Morgan Landfall.



Photograph Courtesy of Transco Pipeline Co.

FIGURE 38. The valve station is located at the top of the bluff in the center of the photograph to the right of the sandy path. Note the railroad tracks in the foreground - post contruction, 1978.



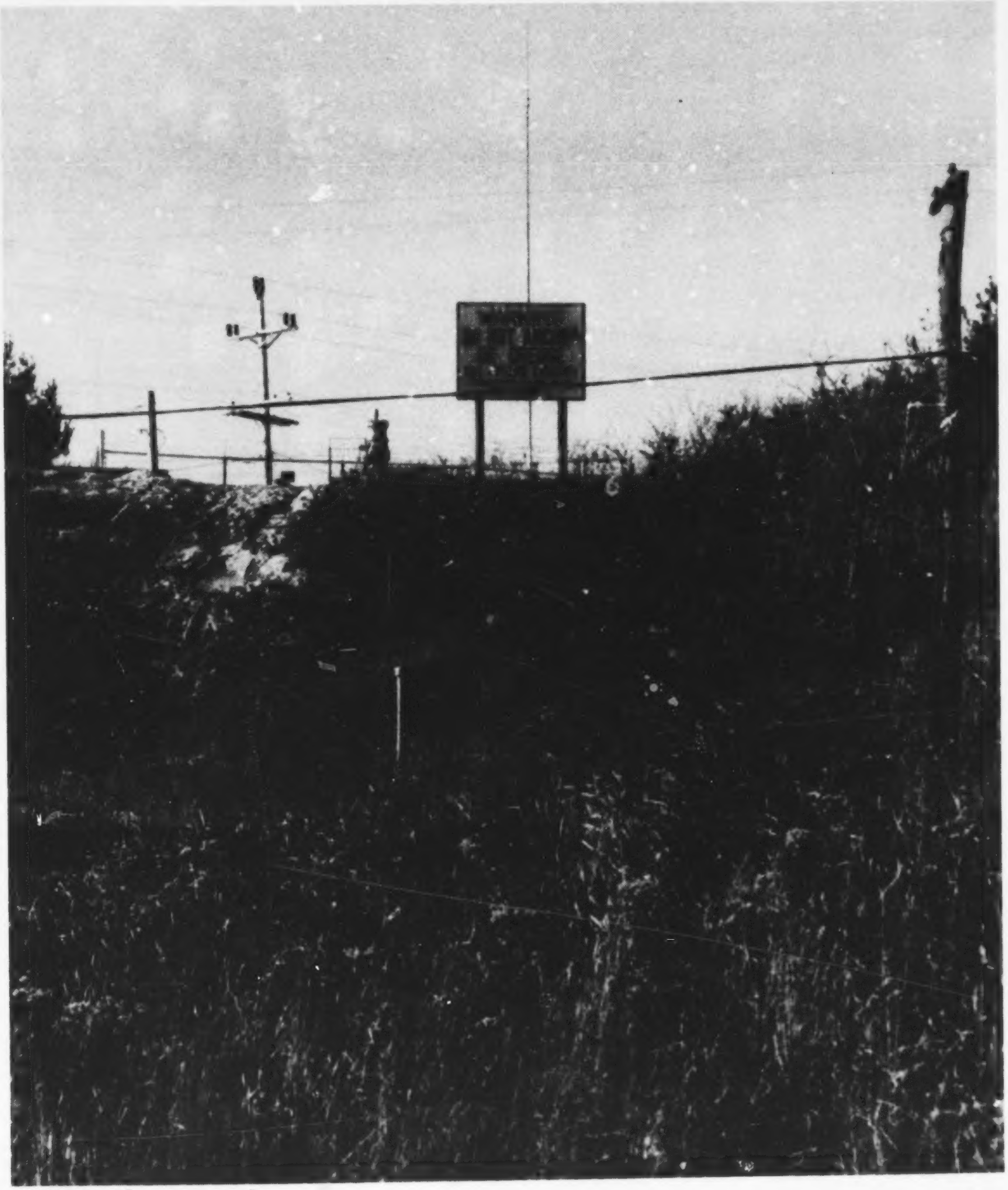
NERBC Photograph.

FIGURE 39. Transco's Valve Station at Morgan, N.J.

used to trench and bury the pipeline, providing five feet of cover over the top of the line. Lastly, the pipeline was hooked into the 42-inch diameter land pipeline transmission system at the valving station on the top of the bluff.

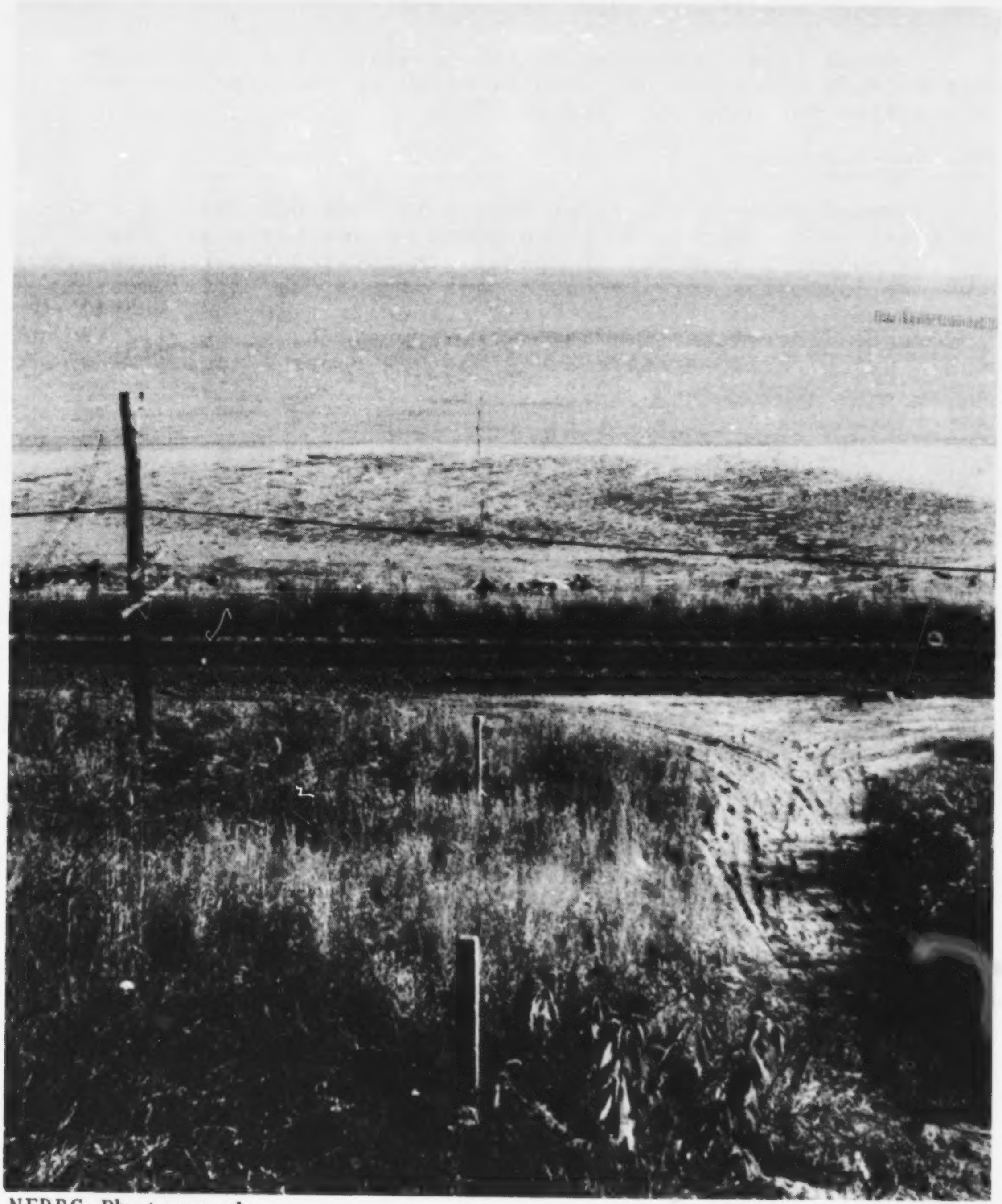
Restoration

The trench and the excavation under the railroad tracks were refilled (providing approximately eight feet of cover) and the original topography at the site restored. The revetment at the edge of the shore was also restored. The landfall was revisited in November 1979, 12 years after the installation. Figures 40 and 41 show that the site remains unchanged and the bluff is well vegetated. The pipeline actually lies to the left of the sandy path visible in Figure 41 under the markers in the center of the photograph.



NERBC Photograph.

FIGURE 40. View Looking up the Bluff. Pipeline is located under the markers in center of the photo, 1979.



NERBC Photograph.

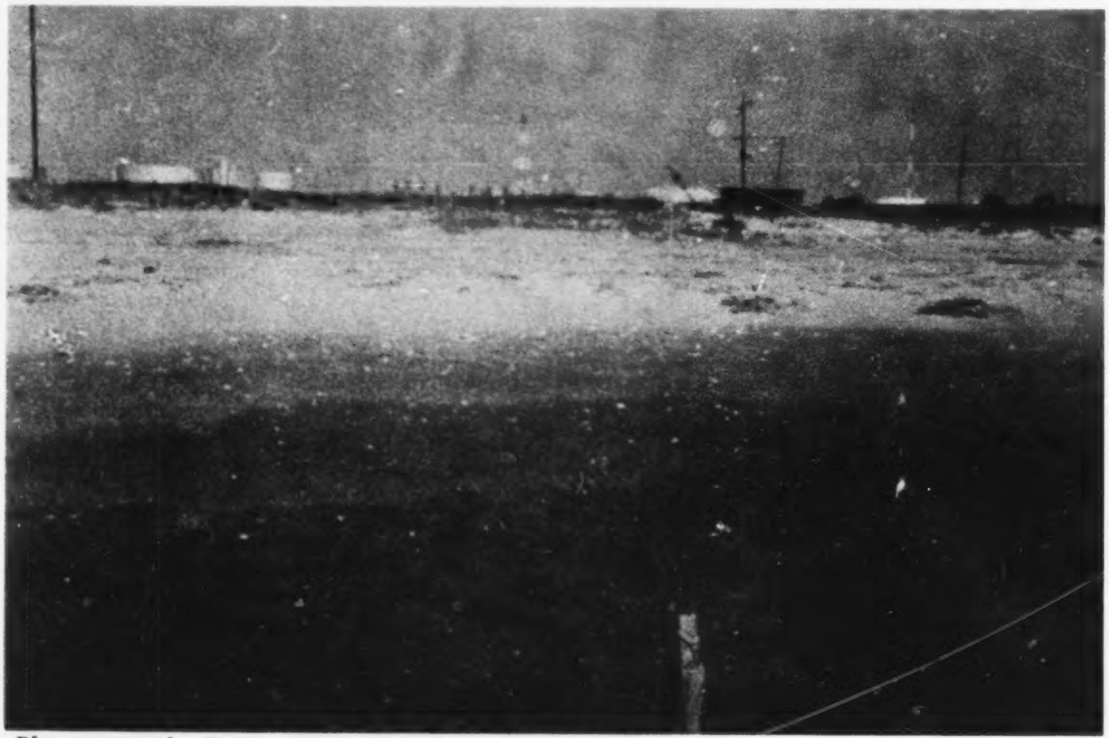
FIGURE 41. View Towards Raritan Bay from Valve Station. Note dense vegetation on the bluff, 1979.

GRAND ISLE, LOUISIANA* (barrier beach)

Grand Isle, Louisiana is the landfall of a 12.75-inch Exxon crude oil pipeline. Construction of the pipeline took place from March through May of 1978.

The Setting

Grand Isle is a barrier island located off the coast of Lousiana approximately 50 miles south of New Orleans. The island supports a number of operations related to offshore oil and gas including service bases, gas processing facilities and an oil/water separation facility. There is also some modest residential development. The shoreline along the barrier island has a wide, gently sloping beach and low dunes (Figures 42 and 43). The right-of-way and permit for the landfall and to the separation facility was acquired from the U.S. Army Corps of



Photograph Courtesy of Exxon Pipeline Co.

FIGURE 42. Looking from Beach Toward Separation Facility Before Construction, February 1978.

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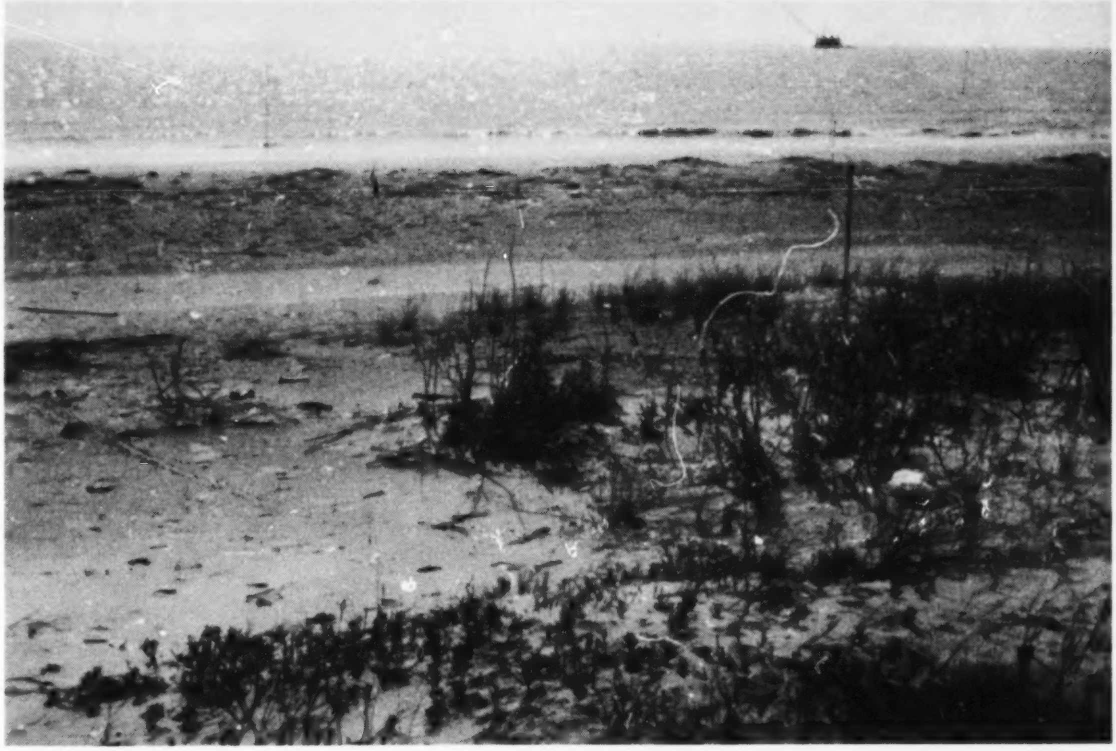
* Primary source of information: George G. Hughes, Jr. (Exxon Pipeline Company, Houston, Texas) 1979: personal communication.



Photograph Courtesy of Exxon Pipeline Co.

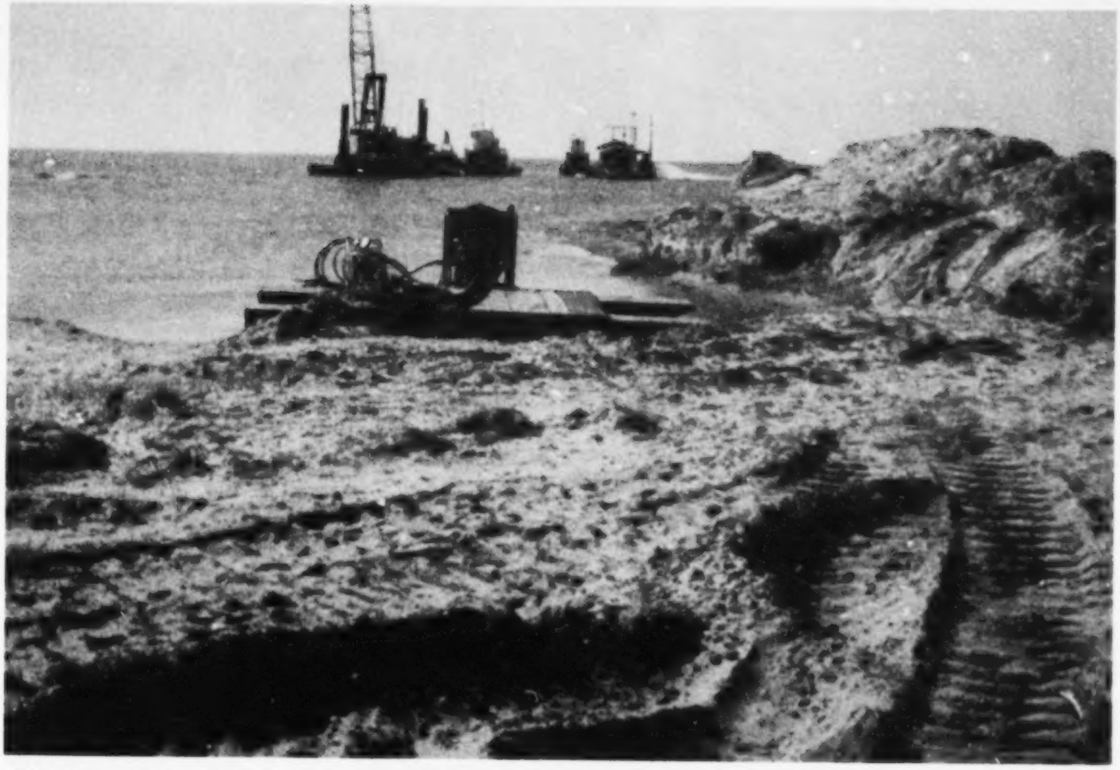
FIGURE 43. Beach Approach Before Construction, February 1978.

Engineers, private landowners, the State of Louisiana, and the town of Grand Isle.

Installation

In March 1978, a 40-foot wide trench was dredged from the beach waterline to a point about 60 feet inland (Figures 44 and 45). From this point landward to the road, a 20 to 25 foot wide trench was excavated, using conventional land excavation methods. From the waterline to the road, the pipe was buried to a depth of approximately 10 feet. From the road to the separation facility, the trench was 15-20 feet wide and burial depth decreased.

The pipeline was installed using the pull method. Lengths of pipe were welded onshore and pulled by the dredge barge into the trench (Figure 46). The total construction and restoration time extended to about three months, primarily due to poor weather conditions. The method of trenching, backfilling and restoration of the landfall was regulated and approved by the

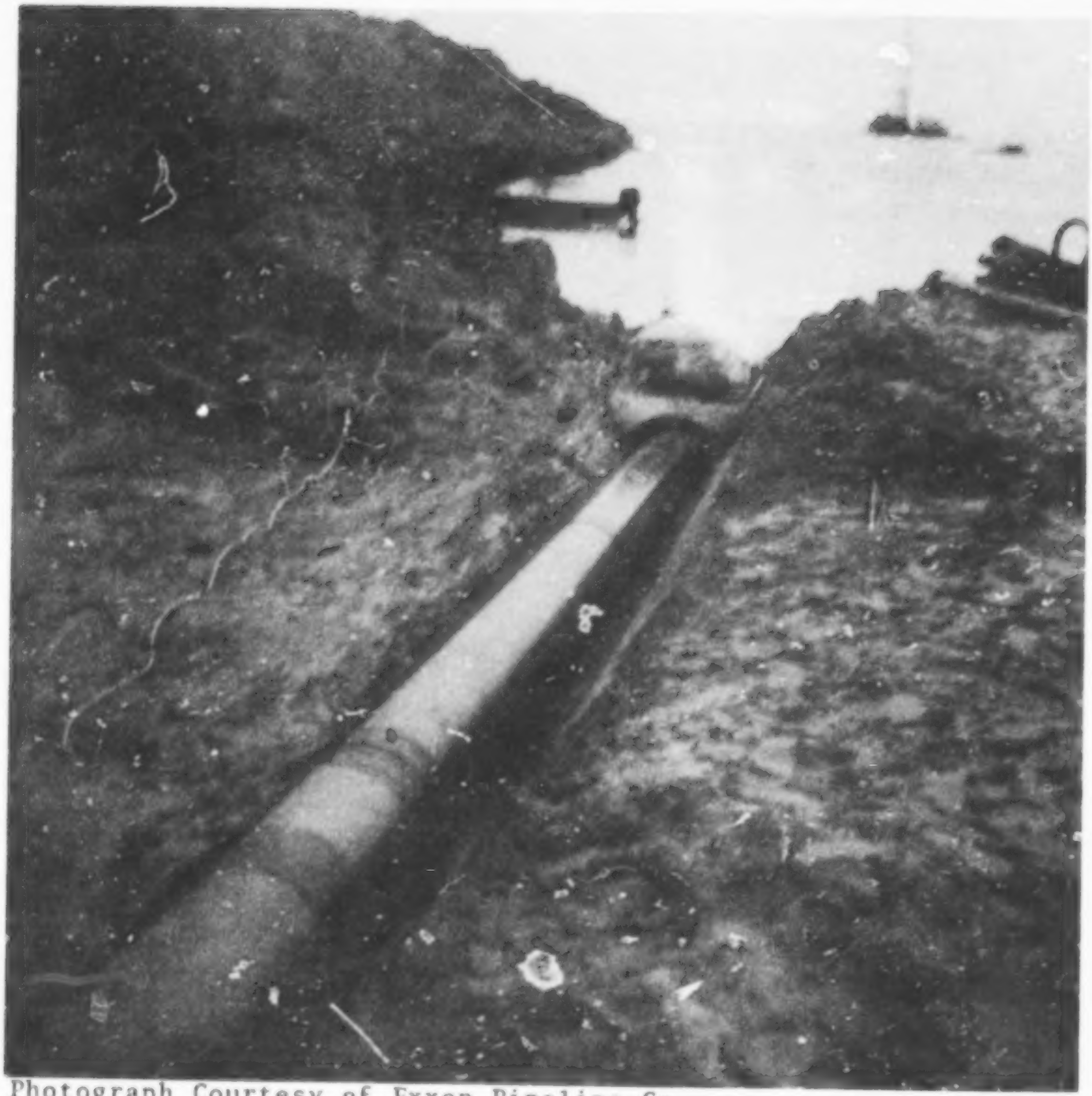


Photograph Courtesy of Exxon Pipeline Co.

FIGURE 44. Dredge Moving into the Shore, March 1978.

Photograph Courtesy of Exxon Pipeline Co.

FIGURE 45. Spoil Material Removed by Dredge, March 1978.



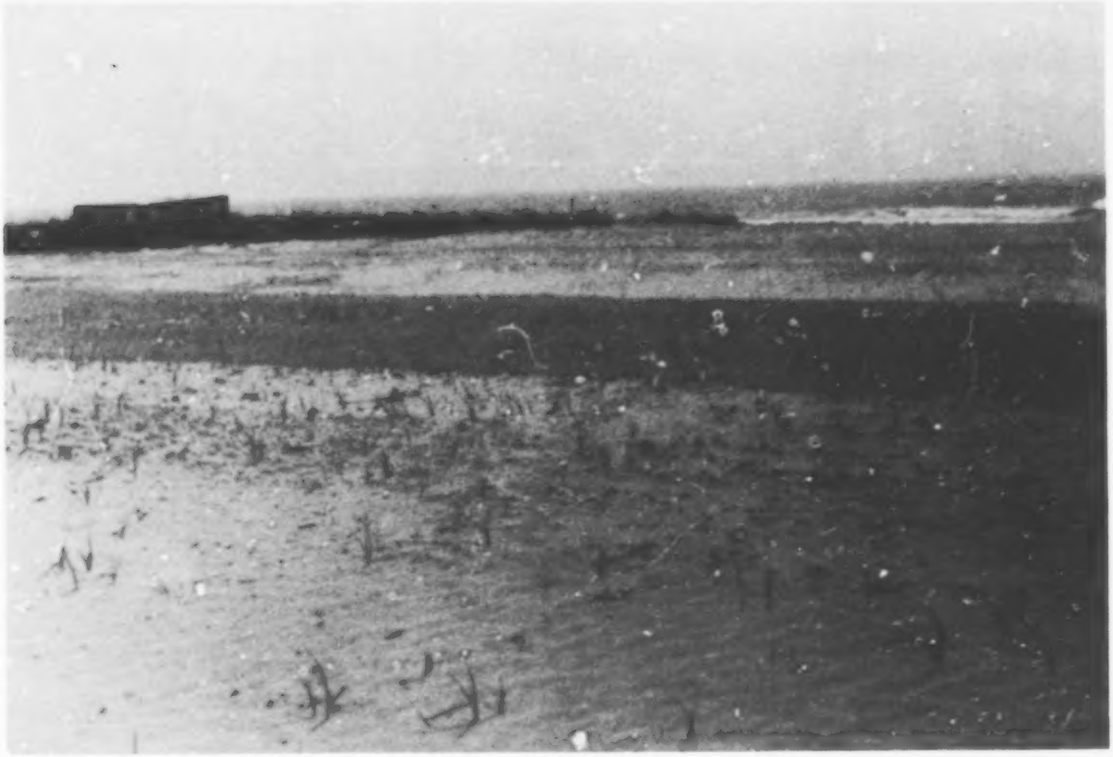
Photograph Courtesy of Exxon Pipeline Co.

FIGURE 46. Pipeline Being Pulled Offshore, March 1978.

U.S. Army Corps of Engineers, the State of Louisiana, and the town of Grand Isle.

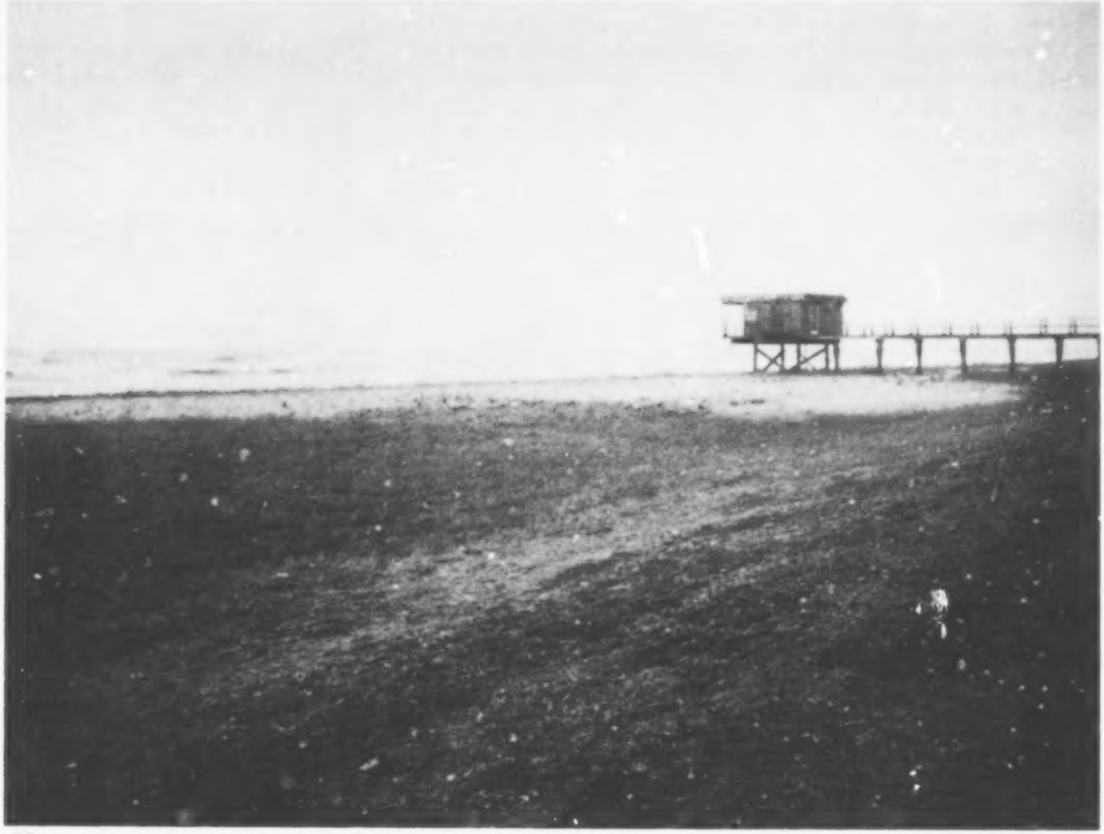
Restoration

The trench was filled and the topography returned to its original condition. No attempt was made to save the top sand layer. Instead, the area was fertilized and replanted with grasses such as bermuda, rye, and bahia. The grass emerged in two to three weeks and at the end of six months, the restoration was essentially complete. Figures 47 through 50 show views of the landfall in May 1978 after restoration and replanting. The site was revisited in July 1979 and the landfall was unrecognizable from the surrounding area (Figures 51 and 52).



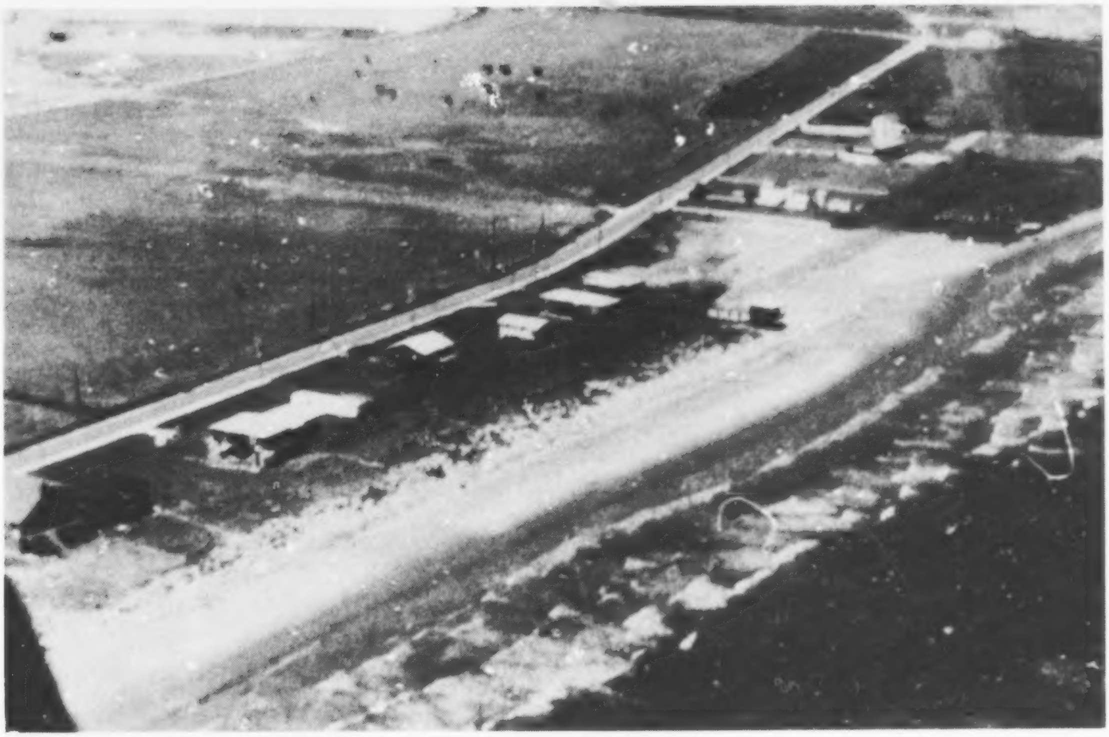
Photograph Courtesy of Exxon Pipeline Co.

FIGURE 47. Beach Cleaned Up and Reseeded After Construction, May 1978.



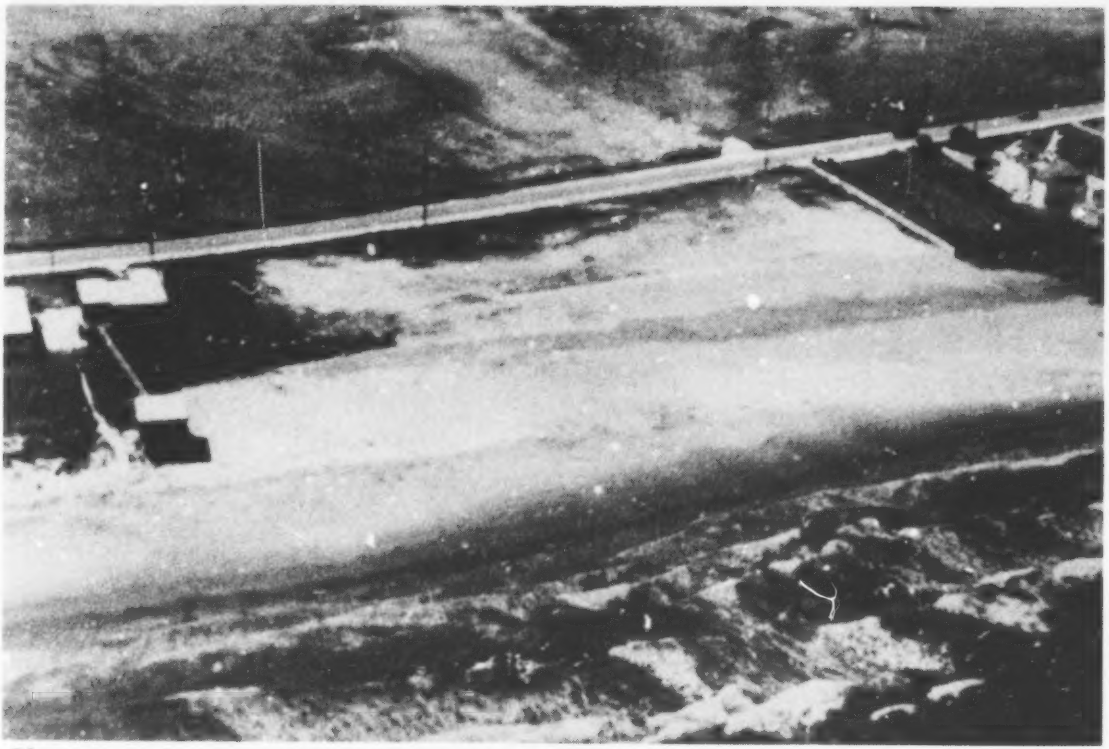
Photograph Courtesy of Exxon Pipeline Co.

FIGURE 48. Another View of Restored Beach.



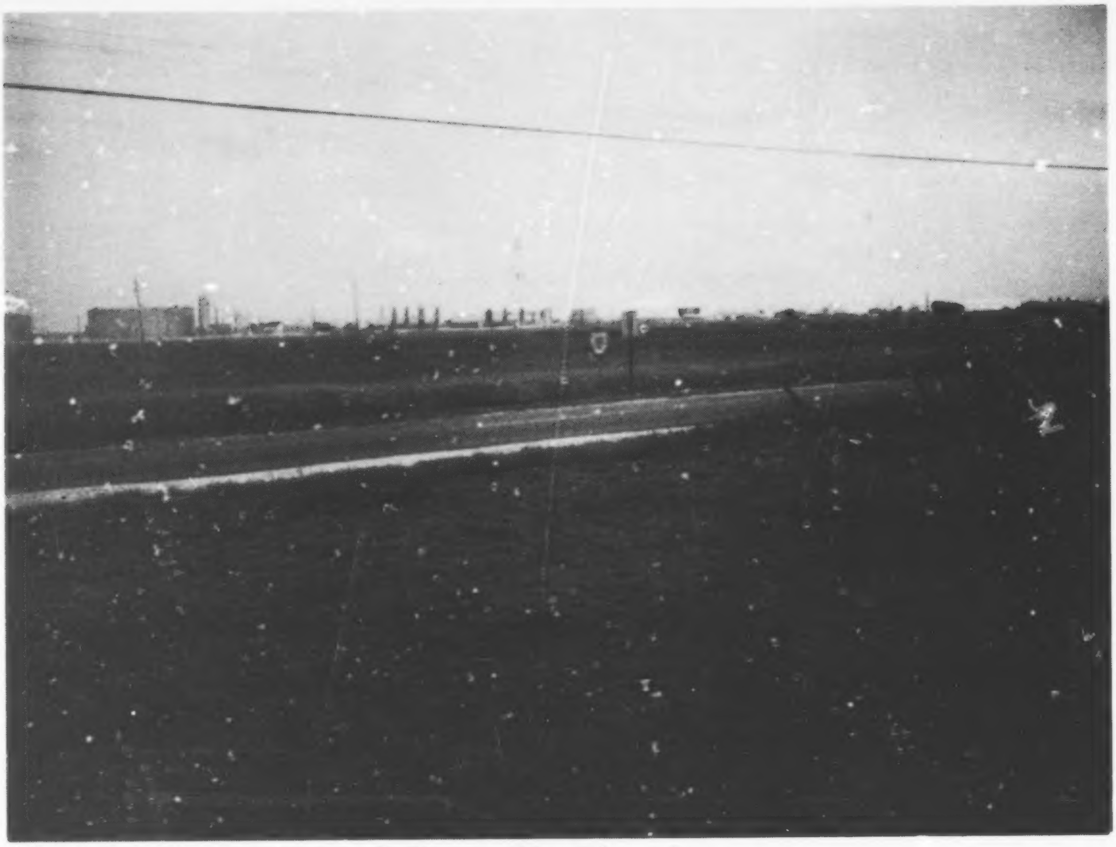
Photograph Courtesy of Exxon Pipeline Co.

FIGURE 49. Aerial View of Landfall Site (Upper Right) After Construction and Clean Up, May 1978.



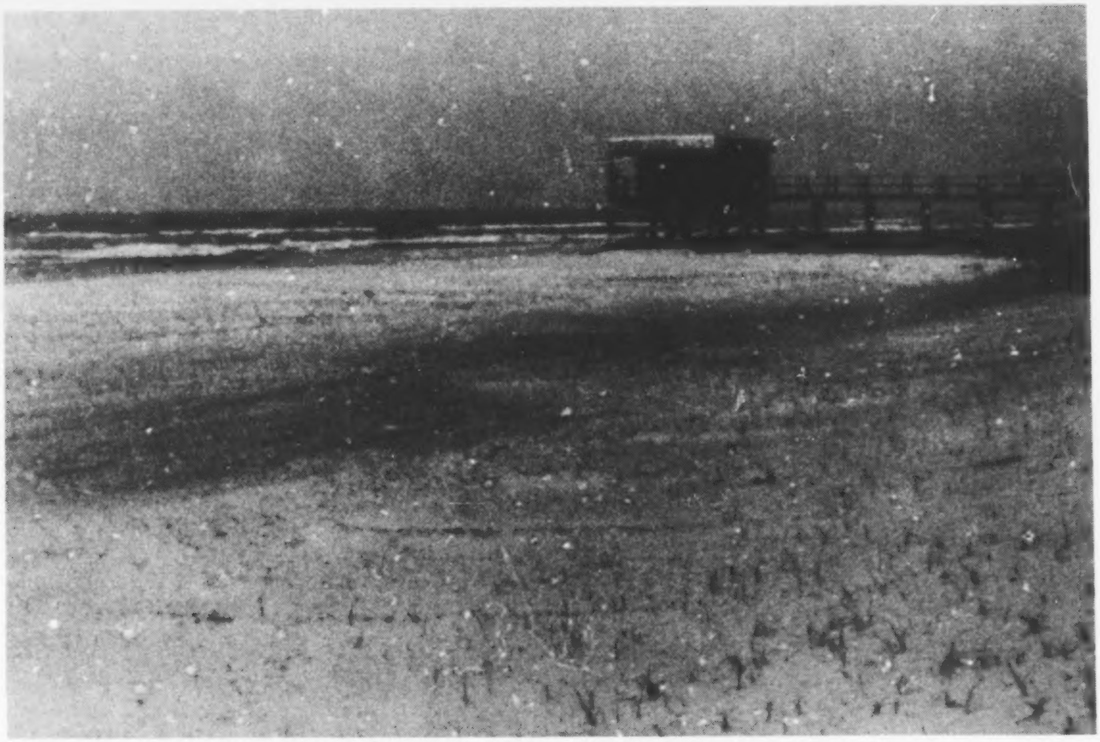
Photograph Courtesy of Exxon Pipeline Co.

FIGURE 50. Close-up View of Beach After Construction, May 1978.



Photograph Courtesy of Exxon Pipeline Co.

FIGURE 51. Appearance of Beach One Year After Construction, July 1979. (Photograph was taken during near miss by hurricane.)



Photograph Courtesy of Exxon Pipeline Co.

FIGURE 52. View of Pipeline Route Behind Beach One Year After Construction, July 1979.

WHISKEY PASS, LOUISIANA* (barrier island/marsh)

A 36-inch diameter gas pipeline built by the Tennessee Gas Pipeline Company crosses a barrier island near Whiskey Pass, Louisiana. Construction of the line took place in 1976 and 1977, connecting offshore production in the Gulf of Mexico to the existing Cocodrie Compressor Station in Terrebonne Parish, Louisiana.

The Setting

The shoreline of Terrebonne Parish is characterized by extensive marshes that are common to the Mississippi River delta region in southern Lousiana (Figure 53). Approximately five

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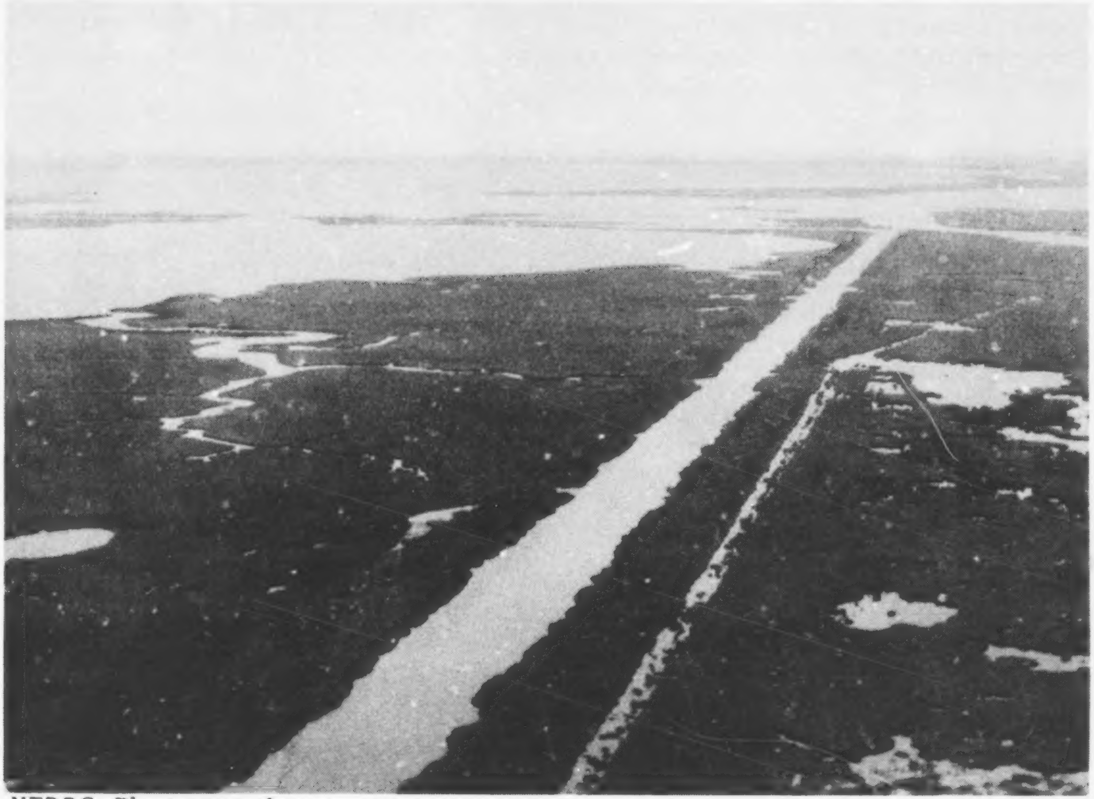
* Primary source of information: H.E. Degreenia, (Tennessee Gas Pipeline, Houston, Texas) 1979: personal communication.



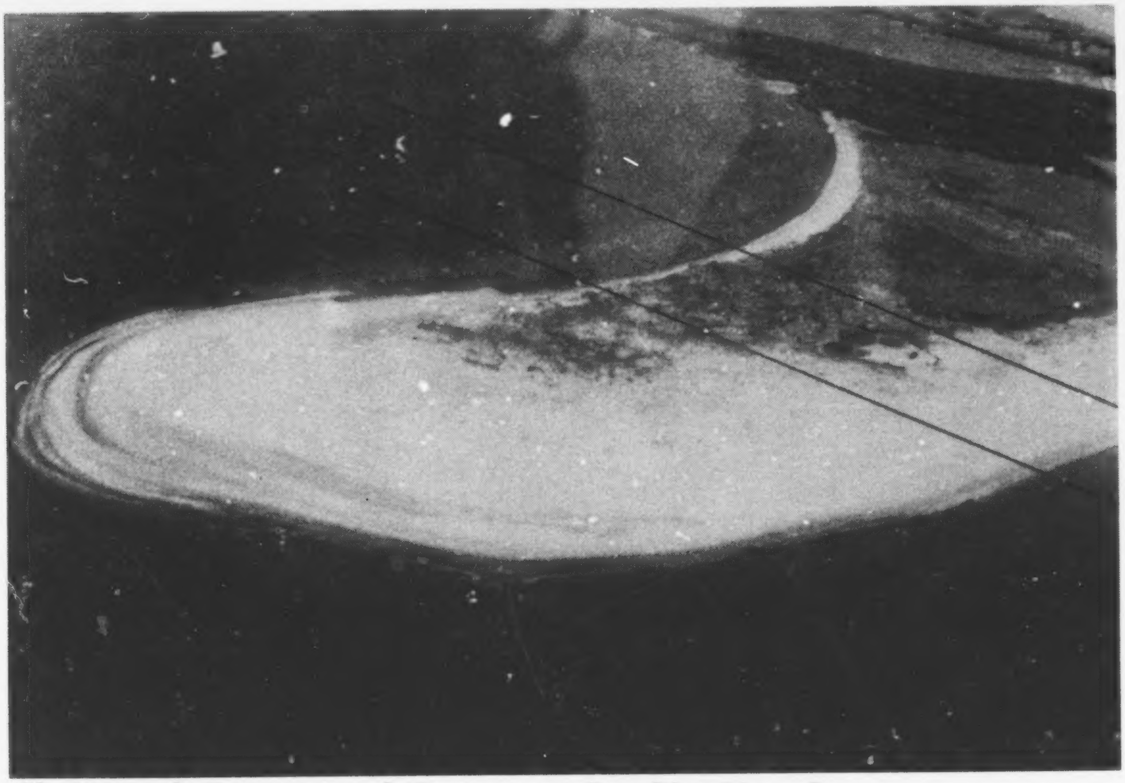
NERBC Photograph

FIGURE 53. An example of the marsh environment of southern Louisiana including a portion of the Blue Water pipeline flotation ditch.

miles offshore is a barrier island with an actively accreting spit at the western end. At the time of construction of the 26-inch Blue Water gas pipeline in 1968 (the same route the 36-inch pipeline follows), the spit was some distance to the east. In the period of time between the route selection for the new 36-inch line and the start of construction, the spit accreted to the west and covered the Blue Water pipeline and the proposed route for the new line (Figure 54). The presence of this new barrier spit presented, therefore, an additional landfall for the pipeline.

Among the agencies involved in regulating the siting and restoration of the pipeline landfall were the following: the Department of Transportation and Development (State of Louisiana), Wildlife and Fisheries Commission (State of Louisiana), Terrebonne Police Jury, State of Louisiana Stream Control Commission, U.S. Army Corps of Engineers, and the

Federal Energy Regulatory Commission. Table 3 lists the various preconstruction surveys undertaken.



Photograph Courtesy of Tennessee Gas Pipeline Co.

FIGURE 54. The barrier island and spit at Whiskey Pass. The location of the two pipelines passing under the spit are shown.

TABLE 3. PRECONSTRUCTION SURVEYS, WHISKEY PASS LANDFALLS

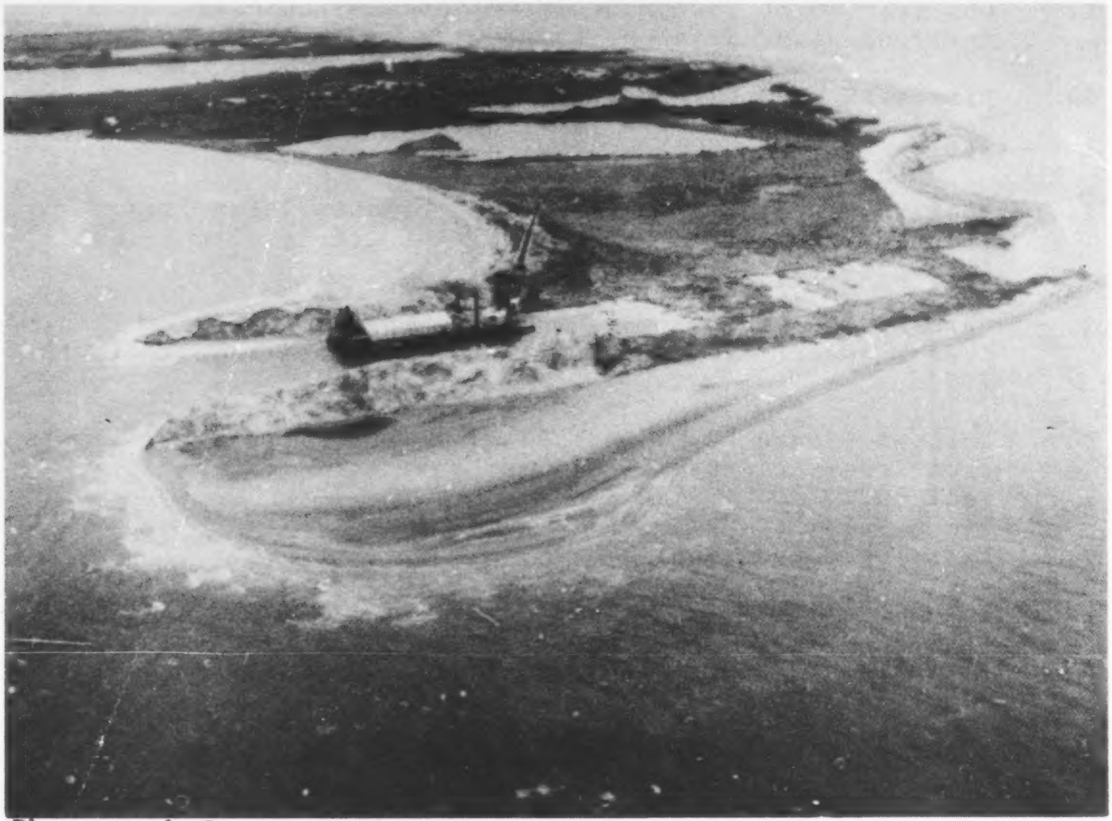
1. Summary of Sedimentary Characteristics of Major Water Bottoms in Area of Proposed Action.
2. Observation of Bottom Sediments and Surrounding Environment at Sampling Points.
3. Biomass Standing Crops (g/m^3) for Plants Taken from Transect Areas of Open Canal at Cocodrie Site -- Fall, 1972.
4. Biomass Standing Crops (g/m^3) for Plants Taken from Transect Areas of Closed Canal at Cocodrie Site -- Fall, 1972.
5. Percent Ground Cover and Relative Compositions for Plants from Transect Areas of Open Canal at Cocodrie Site -- Fall 1972.
6. Percent Ground Cover and Relative Compositions for Plants from Transect Areas of Closed Canal at Cocodrie Site -- Fall 1972.
7. Existing Sound Levels.
8. Water Quality Data -- Sampling Point.
9. Estimates of Sound Pressure Levels, Construction of Pipeline in Marsh Areas.
10. Sound Levels of Additional Compressor Facilities.

Source: Tennessee Gas Pipeline Company, 1979: personal communication.

Installation

Along the offshore sections of the route (beyond the 14 foot water depth), the pipeline was constructed using the conventional laybarge method. This portion of the pipeline was trenched by jetting. A trench was cut in the sea floor eight to ten feet wide and six to seven feet deep, providing a three foot cover over the buried line. Waves and currents were expected to cause burial within one year.

At the barrier island, a 40-foot wide ditch was dredged across the spit to a depth of approximately 14 feet (Figure 55). The dredged sand was piled on either side of the ditch to maintain it (Figure 56). Pipe was welded and lowered off a spud barge into the ditch. The ditch was then refilled using the original dredged sand and the spit was restored to its original grade. The total length of time the island was disturbed was about six weeks.

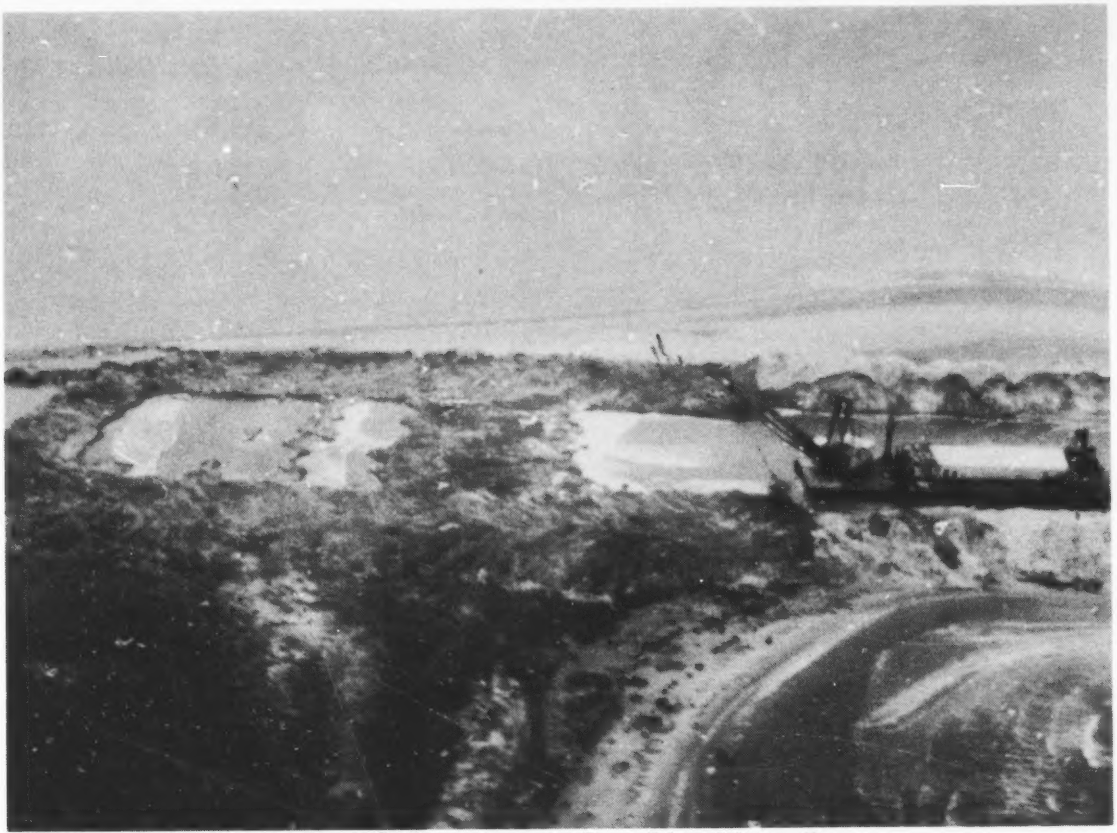


Photograph Courtesy of Tennessee Gas Pipeline Co.

FIGURE 55. Dredging the flotation ditch through the barrier island. The flotation ditch is approximately 40 feet wide and 14 feet deep.

From the 14-foot water depth offshore to the marsh line, a flotation ditch was cut using a dragline on the flotation barge. This ditch was 40 feet wide and six feet deep with an additional five-foot pipeline ditch dug along one side of the canal. Pipe was welded on a spud barge and lowered into the pipeline ditch.

Landward of the marsh line, much of the pipeline was



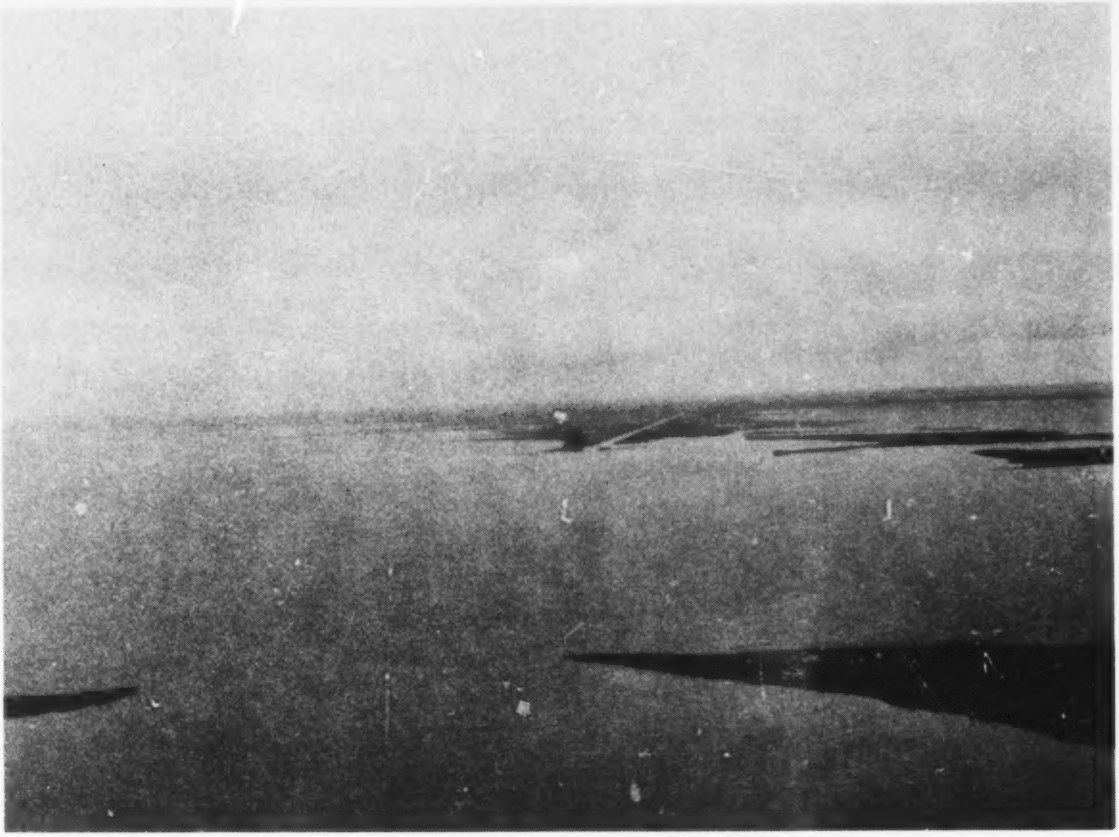
Photograph Courtesy of Tennessee Gas Pipeline Co.

FIGURE 56. Dredged sand is piled on either side of the ditch to maintain it and prevent shoaling.

installed within the existing flotation ditch for the original Blue Water pipeline (Figure 57). A new pipeline ditch was excavated at the side opposite the Blue Water line to place the top of the new pipeline a minimum of ten feet below mean low tide. Where necessary, due to the terrain (numerous marsh islands, bayous and lakes), a new flotation ditch was dug approximately parallel to the Blue Water line and about 100 feet away. The pipeline trench was refilled; however, concrete coating was applied to provide negative buoyancy and protect the line and its corrosion coating. Total length of the pipeline from Ship Shoal Block 144 (offshore) to the Cocodrie Compressor Station is 40.7 miles including approximately 10 miles through the marshes.

Restoration

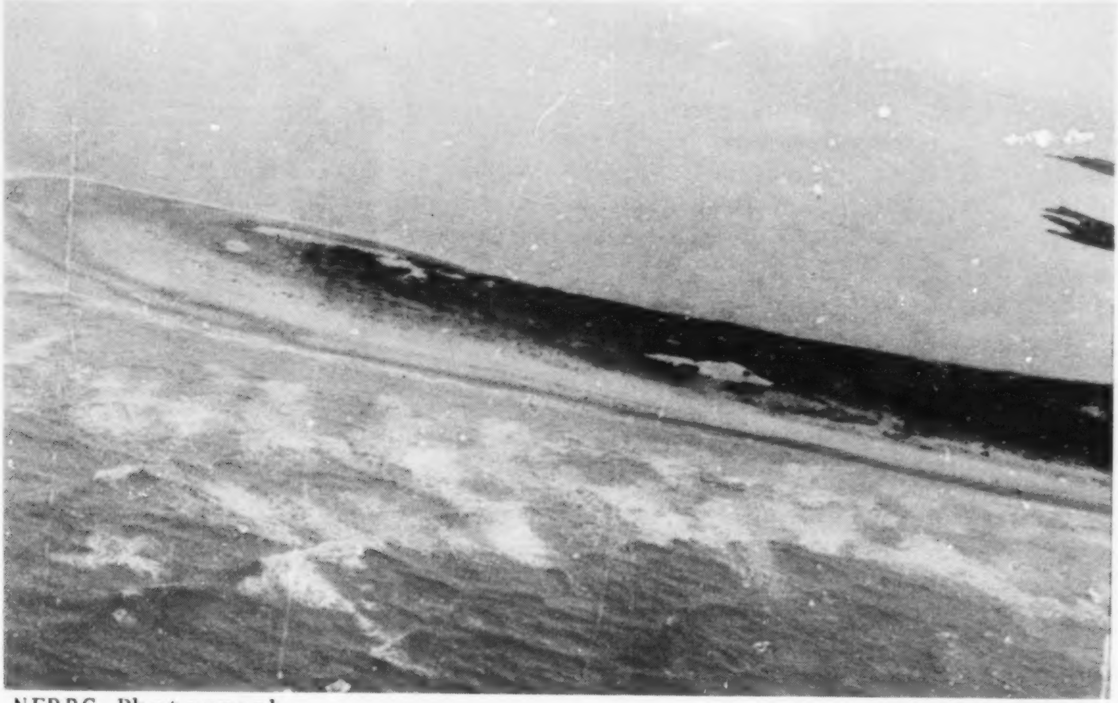
Generally, the land disturbed during construction was



NERBC Photograph.

FIGURE 57. The marsh landfall for the 36-inch pipeline is the existing Blue Water pipeline flotation canal seen in the distance at the center of the photograph.

restored to the original topography and grade, although there was no revegetation. Flotation canals were plugged at intervals to prevent boat traffic. At the end of six months, restoration was judged to be 100 percent. The site of the barrier island crossing was revisited in November 1979, three years after construction, and the site remains unchanged (Figure 58).



NERBC Photograph.

FIGURE 58. The barrier island and spit as they appeared in November 1979. The 36-inch pipeline passes just to the left of the small pond near the center of the photograph.

CRUDEN BAY, SCOTLAND (beach with dunes)

A 32-inch diameter oil pipeline from British Petroleum's (BP) Forties Field reaches land at Cruden Bay in northeast Scotland. The line was the first oil pipeline from the North Sea offshore petroleum development area. Landfall construction took place from February to May 1973. Restoration work took place in two phases in June 1973 and July 1974.

The Setting

The Cruden Bay landfall is situated on a bay-head or pocket beach* in the northeast region of Scotland (Figure 59). The landfall site (Figure 60) consists of a wide, gently sloping sand beach. The beach is flanked by a single line of low, mature dunes which are in an occasional state of erosion due to wave undercutting (Ritchie, 1974). The bay-head location and

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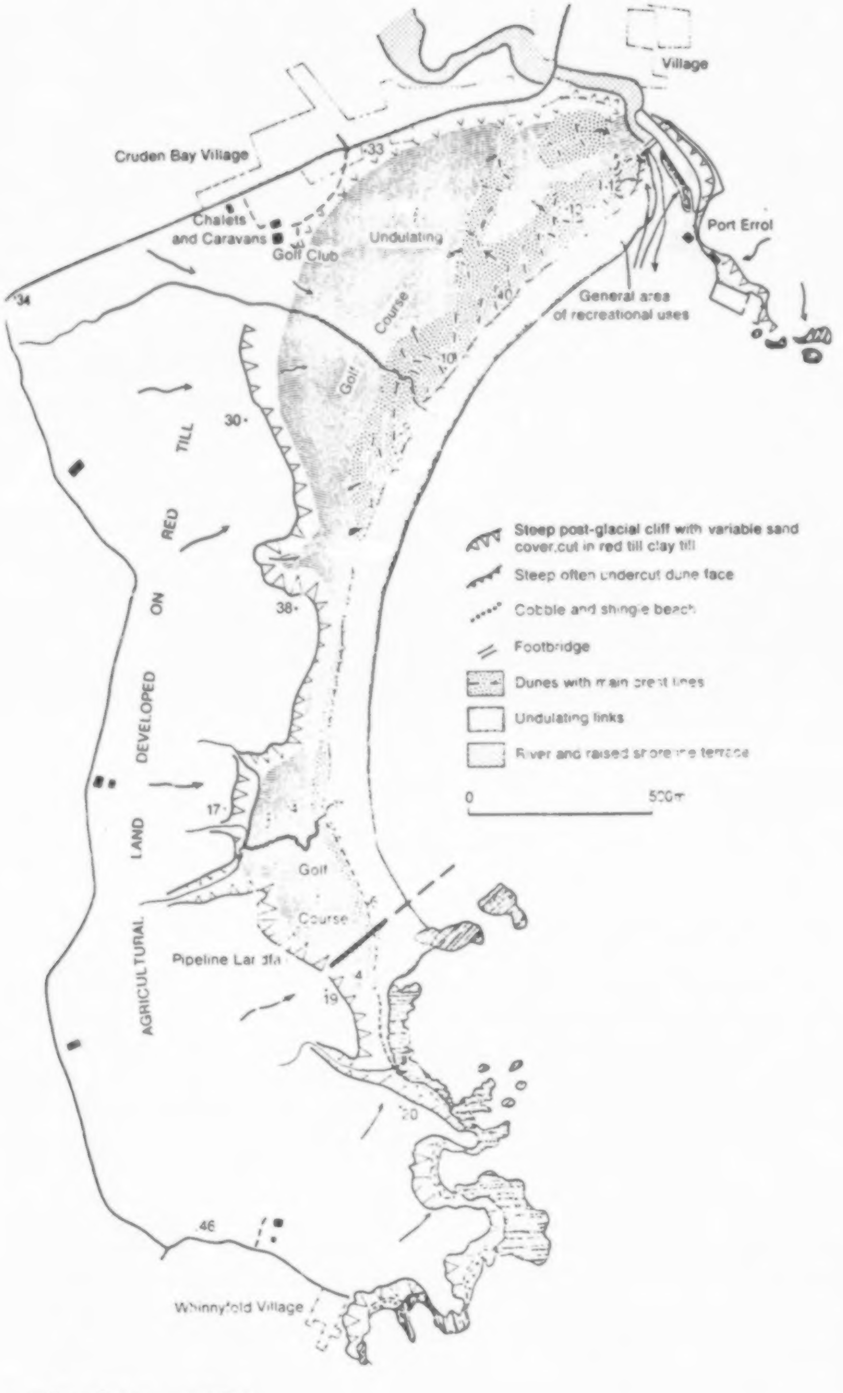
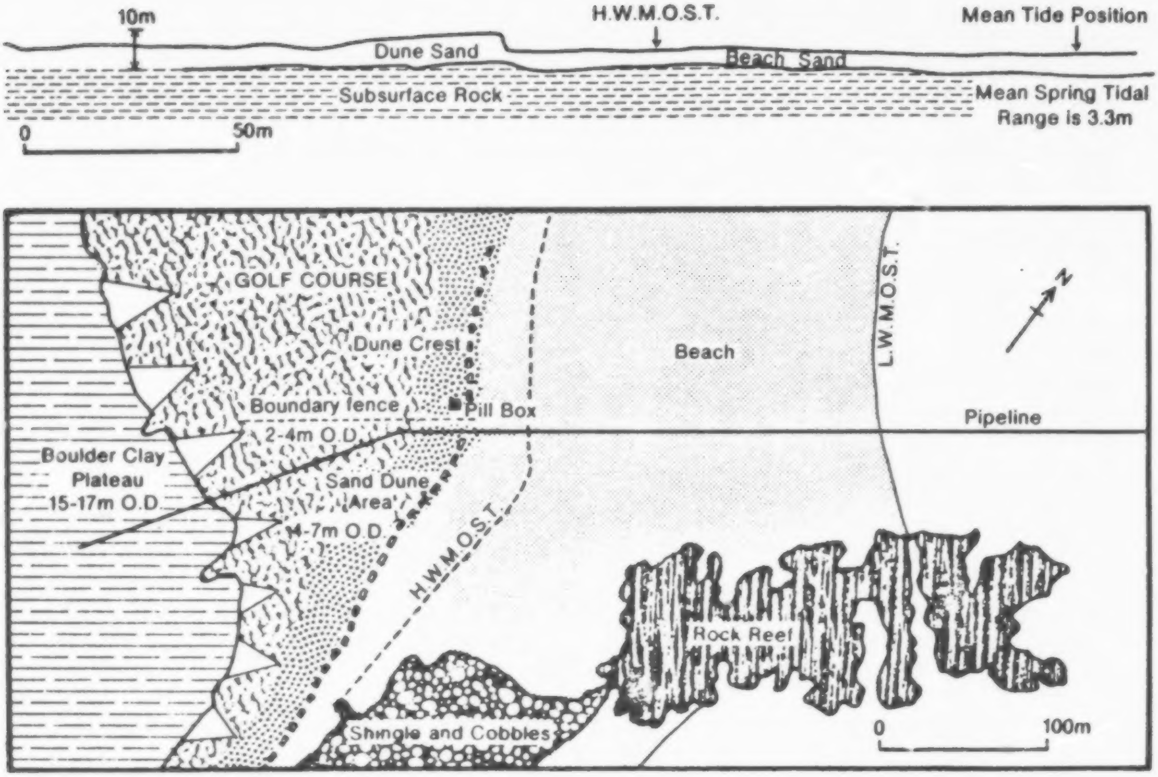
* A crescent-shaped beach composed of sand or shingle situated in a cove between two headlands.


Village
Cruden Bay Village
33
Chalets and Caravans
Golf Club
Undulating
Golf Course
Port Errol
General area of recreational uses
34
30
TILL
RED
ON
DEVELOPED
LAND
AGRICULTURAL
38
17
Golf
Course
Pipeline Landfall
19
46
Whinnyfold Village
Steep post-glacial cliff with variable sand cover,cut in red till clay till
Steep often undercut dune face
Cobble and shingle beach
Footbridge
Dunes with main crest lines
Undulating links
River and raised shoreline terrace
0
500m

Source: Ritchie, 1974.

FIGURE 59. Map Showing the Location of the Cruden Bay Landfall.


10m
H.W.M.O.S.T.
Mean Tide Position
Dune Sand
Beach Sand
Subsurface Rock
Mean Spring Tidal Range is 3.3m
0
50m
GOLF COURSE
Dune Crest
Boundary fence
Pill Box
2-4m O.D.
Boulder Clay Plateau 15-17m O.D.
Sand Dune Area
4-7m O.D.
H.W.M.O.S.T.
Beach
L.W.M.O.S.T.
N
Pipeline
Rock Reef
Shingle and Cobbles
0
100m

Source: Ritchie, 1974.

FIGURE 60. A Detailed Map and General Cross-Section of the Cruden Bay Landfall Site.

the presence of the rock reef to the south provide a degree of protection to the landfall, reducing the amount of dune erosion and subsequent loss of sediment to longshore drift. A portion of a golf course is situated in the area just behind the dunes.

Among the major concerns at the Cruden Bay site were the protection of the neighboring golf course and the "high amenity value" of the Cruden Bay area. Therefore, the specific goals were threefold: (1) not to introduce or initiate beach drifting, dune blowouts, or sand deposition in the adjacent area (e.g., the golf course) or to radically alter drainage patterns; (2) to insure complete and permanent restoration to pre-existing conditions in the shortest time possible; and (3) to maintain a well-managed appearance at the site throughout construction and restoration (Ritchie, 1974).

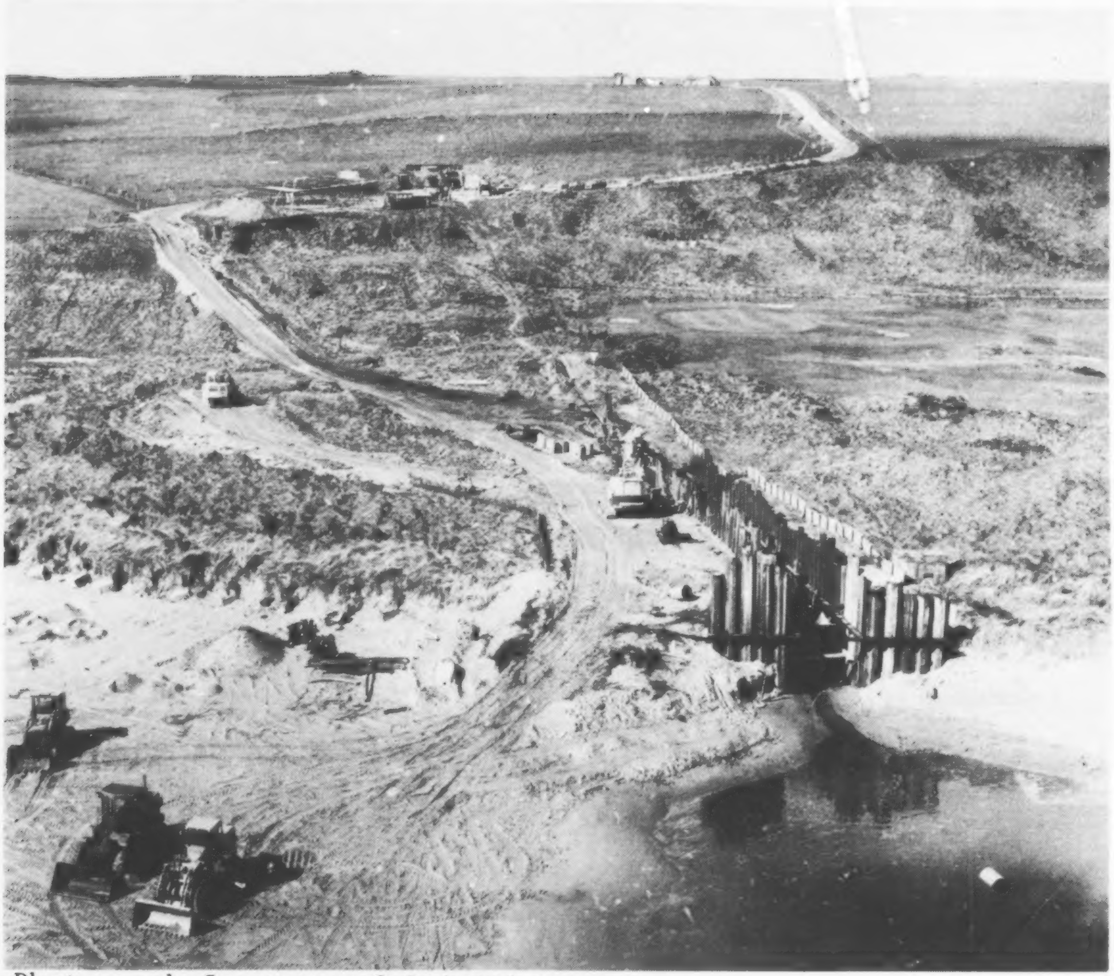
Specialists from the University of Aberdeen provided information on measures needed to minimize impact on the dune environment and the golf course. Preconstruction surveys were undertaken to determine the ecological characteristics for the landfall and the adjacent areas. Then, specific techniques designed to maintain the site's ecologic and aesthetic qualities were chosen. These methods included proper timing of construction activities and particular attention to cutting through and restoring the dunes.

Installation

Work began in February 1973 with the excavation of a trench through the dunes behind the beach. This early start was desired to complete construction activities before the golf course became heavily used in the summer. Standard land excavation techniques were used to dig the four-meter-wide trench; sheet piling maintained the trench's stability (Figure 61). The upper topsoil/vegetative layers were removed and stored in a hollow behind the dunes. The lower layers of sand were excavated and divided into two halves. Dune restoration plans called for mixing the original dune sand with topsoil, requiring only one-half the amount excavated. The half needed for restoration was stored behind the dune; the remaining half was dumped a short distance offshore to return to the beach and dune by natural processes (Moffat, 1973).

Three methods were used to prevent wind erosion and blowing sand at the construction site. First, the sand pile stored onshore was covered with five to ten centimeters of clay-rich soil to prevent blowing sand and wind erosion and to retain moisture. Vegetation grew on this retentive soil layer, helping to visually conceal the unattractive storage area (Ritchie, 1974). Second, brushwood fences were built, using standard fence posts with two or three strands of wire. Branches of conifers were woven between the wires to produce a barrier that would serve as a wind screen and help retain sand. An attempt was made to achieve a 40 percent fence porosity, a value suggested as being an ideal wind screen by previous research (Ritchie, 1974). Third, areas susceptible to wind erosion were sprayed with a bitumin substance known commercially as "Crelawn." This water-based emulsion is biodegradable, gradually disintegrating into discrete patches and finally granules. All three methods worked effectively in maintaining stability at the construction site and preventing sand deposition on the golf course (Ritchie, 1974).

The pipeline pull took place in May 1973. The trench through the beach was excavated just before the pull. Lengths of 32-inch diameter pipe were welded offshore and pulled onshore by winch. Following the pull, sheet piling was removed, the trench was refilled and restoration work began.



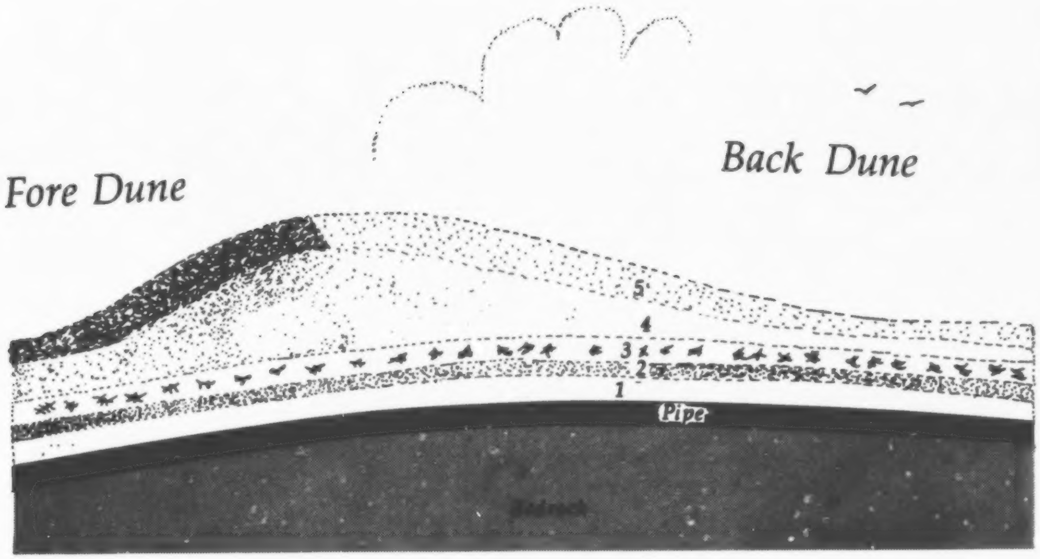
Photograph Courtesy of British Petroleum.

FIGURE 61. Excavation of a Sheet Pile Trench Through the Dunes, May 1973.

Restoration

Delays occurred in connecting the land pipeline to the ocean pipeline, so restoration was carried out in two phases: (1) dune reconstruction and revegetation in June 1973 and, (2) restoration and revegetation of the area behind the dune in spring and summer 1974.

Following removal of the sheet piles, the trench through the dunes was refilled as follows (Figure 62):



Source: after Moffat, 1973.

FIGURE 62. A Generalized Cross-Section Through the Dunes at Cruden Bay Showing the Layers of Materials Used to Refill the Trench.

1. the pipeline was initially covered with one meter (3.3 ft) of sand;

2. over the sand layer, crushed granite was added to a depth of 30 centimeters (approximately 1 foot);

3. a second one-meter layer of sand was placed over the granite. The tops of Scotch Pine trees were embedded in this layer to further stabilize the final dune structure;

4. an equal mixture of topsoil and sand was filled in around the tree tops to just below the original level of the dune; and

5. a final 30-centimeter layer of topsoil and sand (2 parts topsoil to one part sand) was added to restore the original dune level. On the fore dune slope, the final layer was equal parts sand and topsoil (Nieuwborg, 1977).

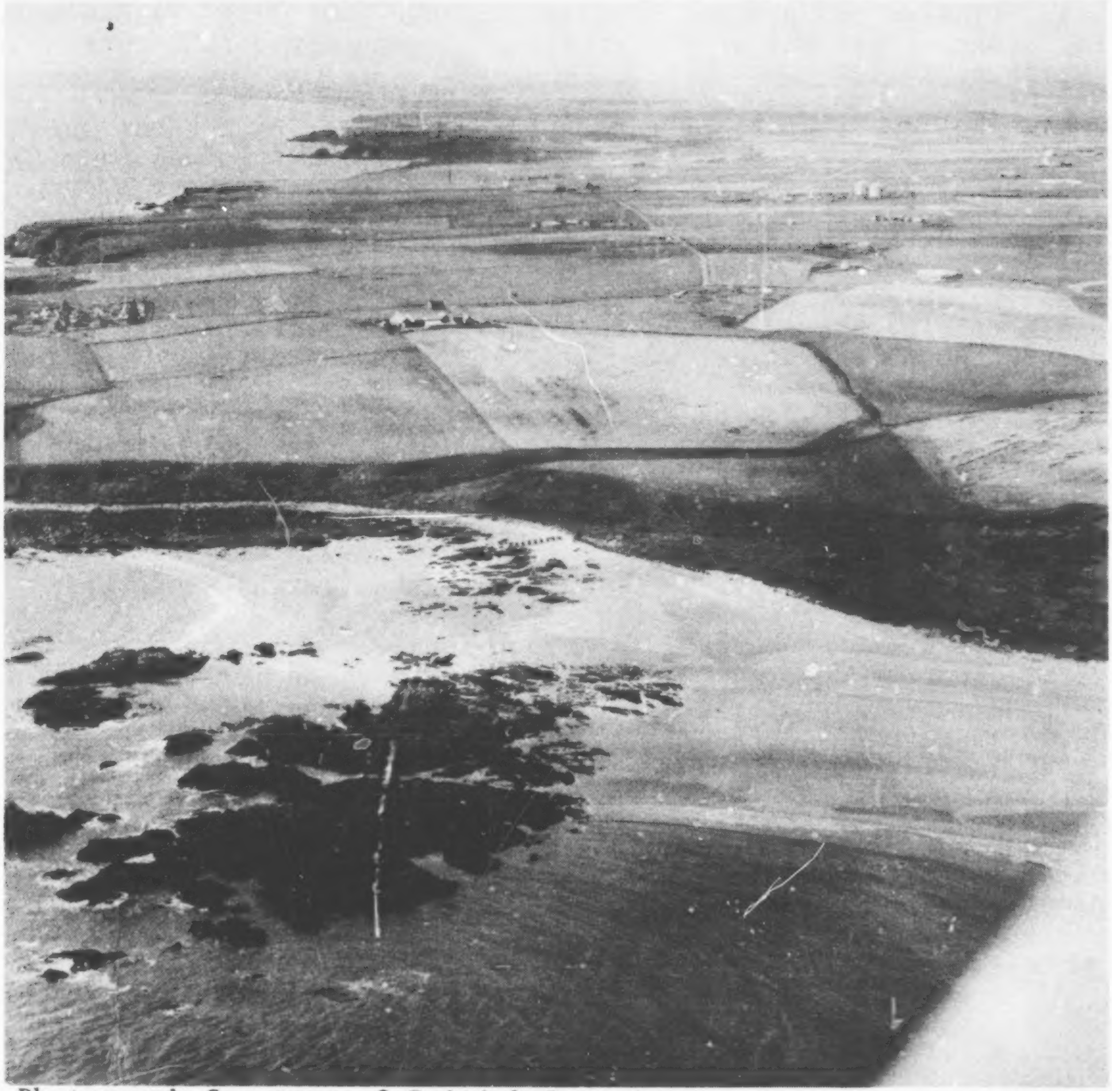
After the trench was filled, the dune and back slope were rolled to compact the sediments. Revegetation was accomplished by sowing a mixture of grasses (rye grass, smooth stalked meadow grass, red fescue and agrostis) along with a slow-release, nitrogen-rich fertilizer. Additionally, the area was sprayed with "Crelawn" to prevent erosion (Nieuwborg, 1977). Within a few weeks, there was a good growth of vegetation on the dune (Ritchie, 1974).

The dune face slope was restored, but set back about one-half meter (1.5 feet) to allow for accretion of the dune face, and the slope was reduced to about 20 degrees to improve slope stability. Tree branches held down by netting were laid on the slope to maintain it. Brush fencing was placed diagonally to the beach at the base of the dune to encourage accretion in this area (Ritchie, 1974). Throughout the first year's restoration, brush fencing placed during construction was left in place to reduce the potential for wind erosion and sand drifting.

In March 1974, the second phase of restoration began. The trench behind the dune back to the old cliff line was refilled and the area revegetated. The same revegetation method was used for this area as for the dune except Crelawn was not sprayed. The dune face was hand planted with Ammophila arenaria (European beach grass), the predominant native species, and Elymus arenarius (Sea Lyme grass) which spreads easily and has a high salt tolerance. Ammophila was also planted in the sand accreted at the base of the dune by the brush fences. The grasses planted on the dune the previous year were given a single cutting in June 1974 (Ritchie, 1974). Figure 63 shows the appearance of the landfall site two years after restoration (August 1975).

Four years after restoration, a vegetation survey (Nieuwborg, 1977) was conducted at the landfall site to determine the success of the restoration work. Among the conclusions reached were:

- most grasses on the sand dune had increased along with the invasion of new grasses and herbs;
- sand accumulation inhibited the growth of grasses in some areas especially on the back dune;
- grazing on some portions of the back dune area inhibited revegetation success; and
- the application of topsoil created soil conditions that stimulated vegetational growth.



Photograph Courtesy of British Petroleum.

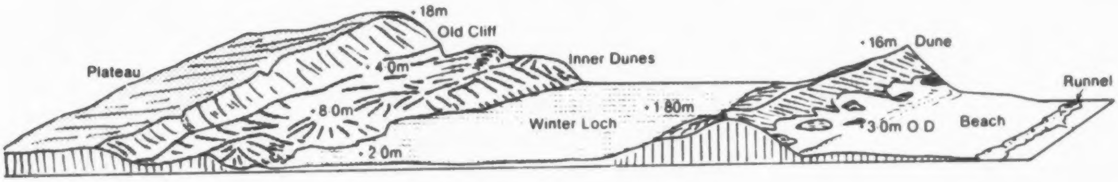
FIGURE 63. A View of the Cruden Bay Landfall Two Years After Restoration, September 1975. Line indicates approximate pipeline location.

ST. FERGUS, SCOTLAND (The Total "Frigg" Pipeline) (beach with steep dunes/wetland)

St. Fergus is the location of the landfall for Total's twin 32-inch diameter gas pipelines from the Frigg gas field in the North Sea, a distance of 225 miles offshore. A second landfall for the Shell "FLAGS" gasline from Brent Field is located next to the Frigg landfall. The "FLAGS" landfall is discussed in detail in Section 5. Construction on the Total Frigg landfall took place over a 20-month period from March 1974 to October 1975.

The Setting

St. Fergus is located in northeast Scotland on the North Sea. The shoreline at St. Fergus (Figure 64) has a steep beach bordered by frontal dunes up to 16 meters (50 feet) high with slopes of up to 20 degrees (Figure 65). Behind the dune field is a wetland (called the Winter Loch) and a second field of older dunes (Figure 64). The St. Fergus gas processing complex is located on the plateau landward of the inner dunes.



Source: Ritchie et al., 1979.

FIGURE 64. The morphology of the St. Fergus landfall showing the relationships of the various land forms. The Winter Loch is a seasonal fresh water wetland.

The nearshore area off St. Fergus contains numerous rock and hard clay outcrops and is subject to strong currents; therefore, due to these constraints and water depth restrictions, the closest the pipelaying barge could be brought to the shore was 1500 meters (approximately one mile). Problems encountered with pipeline operations in this nearshore area stretched what was projected to be an eight month project into one some eighteen months long.

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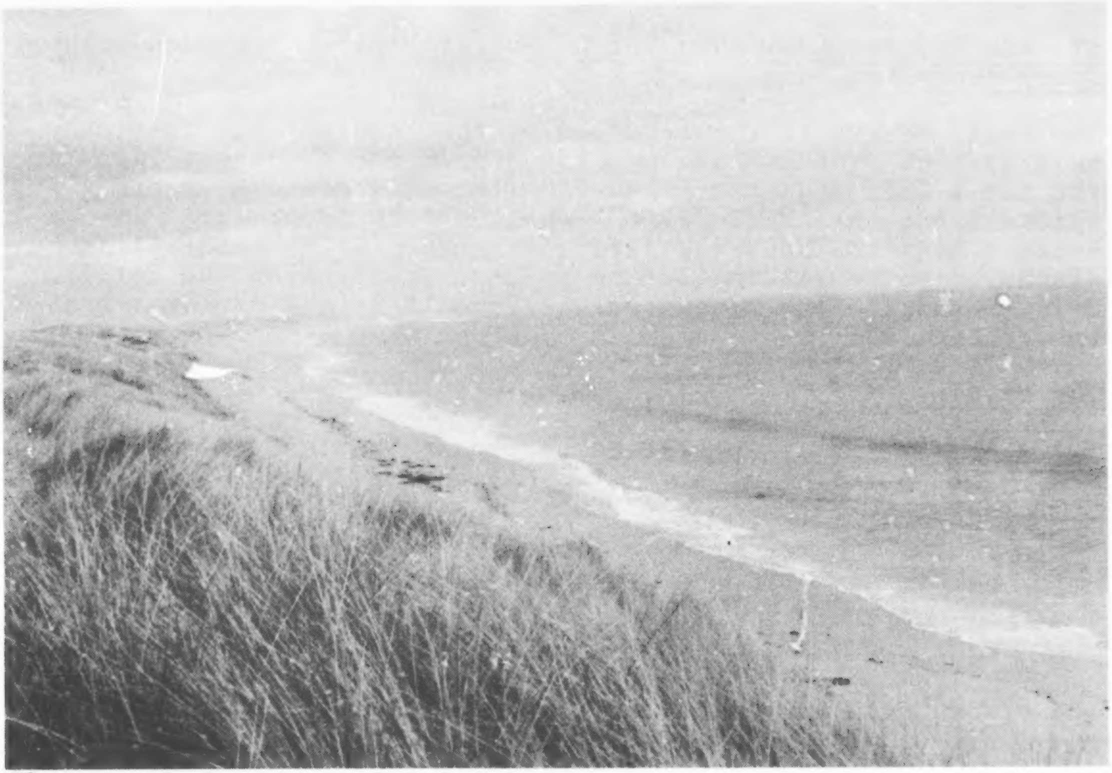
* Primary source of information: J.M. Reynolds, (Land and Marine Engineering, Ltd., England) 1979: personal communication.



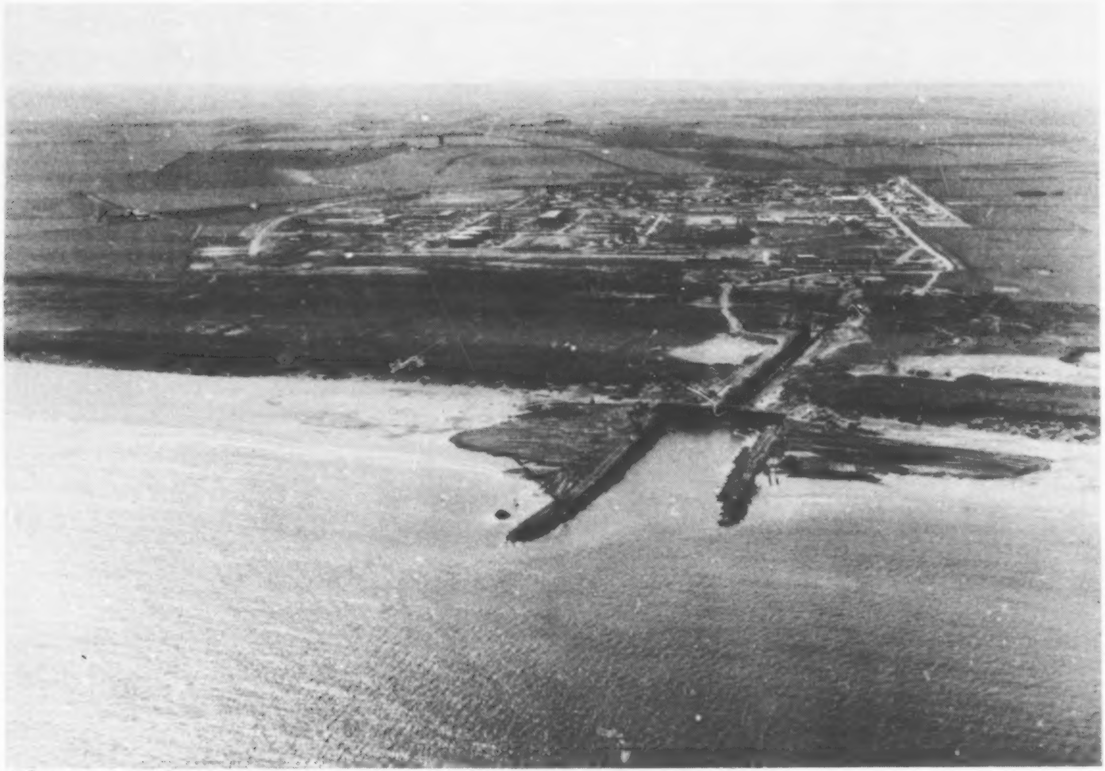
Photograph Courtesy of British Gas.

FIGURE 65. A View of the Large 16 Meter High Dunes at St. Fergus.

The Winter Loch area was of particular interest to environmentalists due to its importance as a wildfowl feeding area. To preserve the Winter Loch, the dunes, which provided a great deal of protection, had to be maintained in a stable condition which prevented blowouts (wind erosion and breaching) and sand infilling, or sea water inundation of the loch.

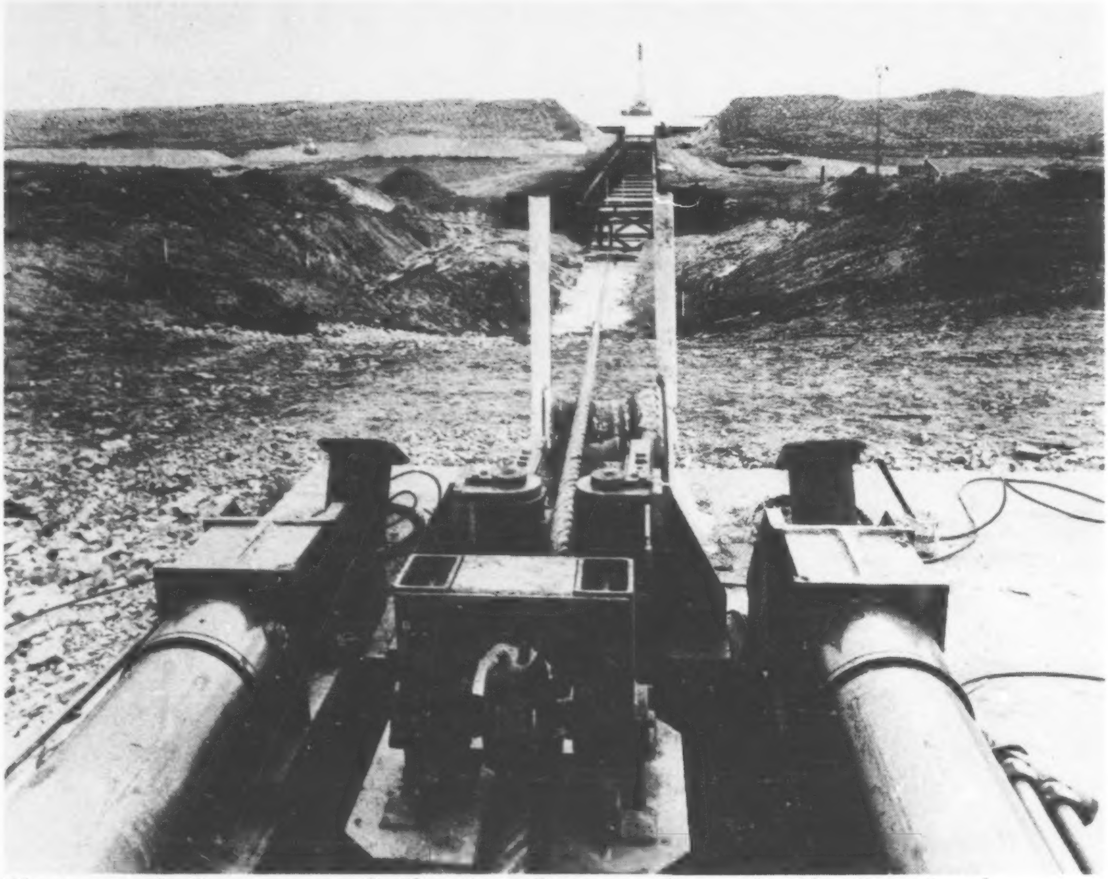
Installation

The lay barge was anchored 1500 meters (about one mile) offshore. The nearshore route passed through rock and clay which required blasting; through sandy areas, draglines were used to dig the pipeline trench to the low water mark. A sheet pile-lined trench was excavated from the high water mark, through the frontal dunes and Winter Loch (Figures 66 to 68). This trench was 320 meters (1050 ft.) long, 10 meters (33 ft.) wide, and provided for a cover depth of 4 meters (13 ft.) through the dunes and 2 1/2 meters (8.25 ft.) through the loch. Sand from the excavation was stored in the Winter Loch area; no



Photograph Courtesy of British Gas.

FIGURE 66. An Aerial View of the St. Fergus Landfall During Construction. Note the sheet pile lined trench through the dunes and Winter Loch. The St. Fergus gas complex is in the background.

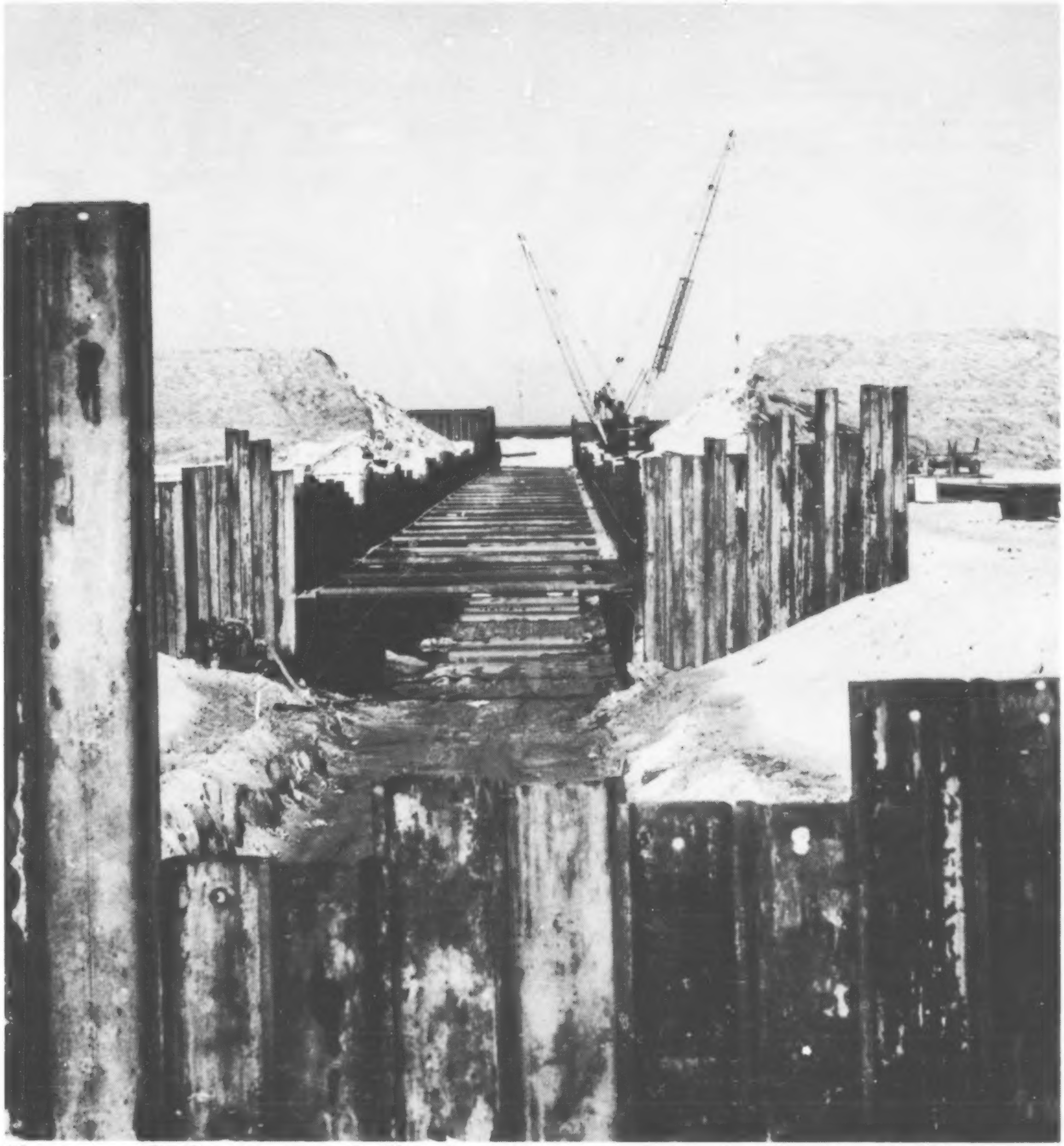


Photograph Courtesy of Charles Fraser, Peterhead, Scotland.

FIGURE 67. A View of the Winch Site and Sheet Pile Trench, St. Fergus.

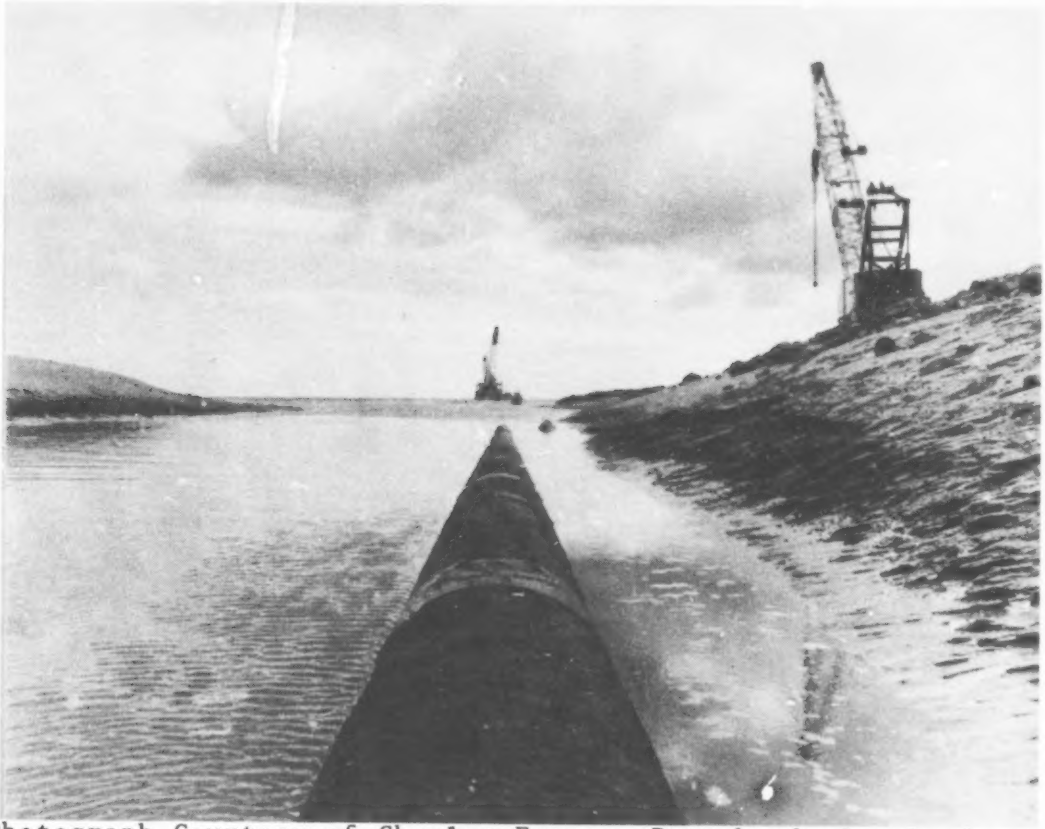
attempt was made to save the upper vegetative layer.

The land excavations and pipeline pull were completed in the summer of 1975. Twenty-five-meter (82 ft.) joints of 32-inch diameter pipe with 4.625-inch concrete coating were welded on the laybarge and pulled onshore (Figure 69) by 100 and 150 ton winches equipped with 2.25-inch wire cable. After each pipeline was pulled past the loch to the inner field of sand dunes, the offshore end of the pipeline was capped and lowered to the sea floor for future connection with the remainder of the offshore pipeline system.



Photograph Courtesy of Charles Fraser, Peterhead, Scotland.

FIGURE 68. The Sheet Pile Lined Trench at St. Fergus.



Photograph Courtesy of Charles Fraser, Peterhead, Scotland.

FIGURE 69. The Frigg Pipeline Being Pulled Onshore from the Lay Barge in the Distance.

Restoration

In the nearshore, pipeline burial was achieved using a submersible trenching machine operated from a workbarge (Figure 70). The machine provided two meters of cover (6.5 feet) in sandy material. Onshore, sheet piling through the dunes and Winter Loch was removed and the trench refilled. Restoration of the frontal dunes was difficult due to erosion occurring naturally at the site. After pipe installation, the trench through the dune was refilled first with clay material replacing the original base layer followed by gravelly sand and finally, dune sand. The surface of the dune was then stabilized and revegetated. A gabion* mattress was buried in the toe of the dune to aid in limiting erosion due to wave attack (Figure 71).

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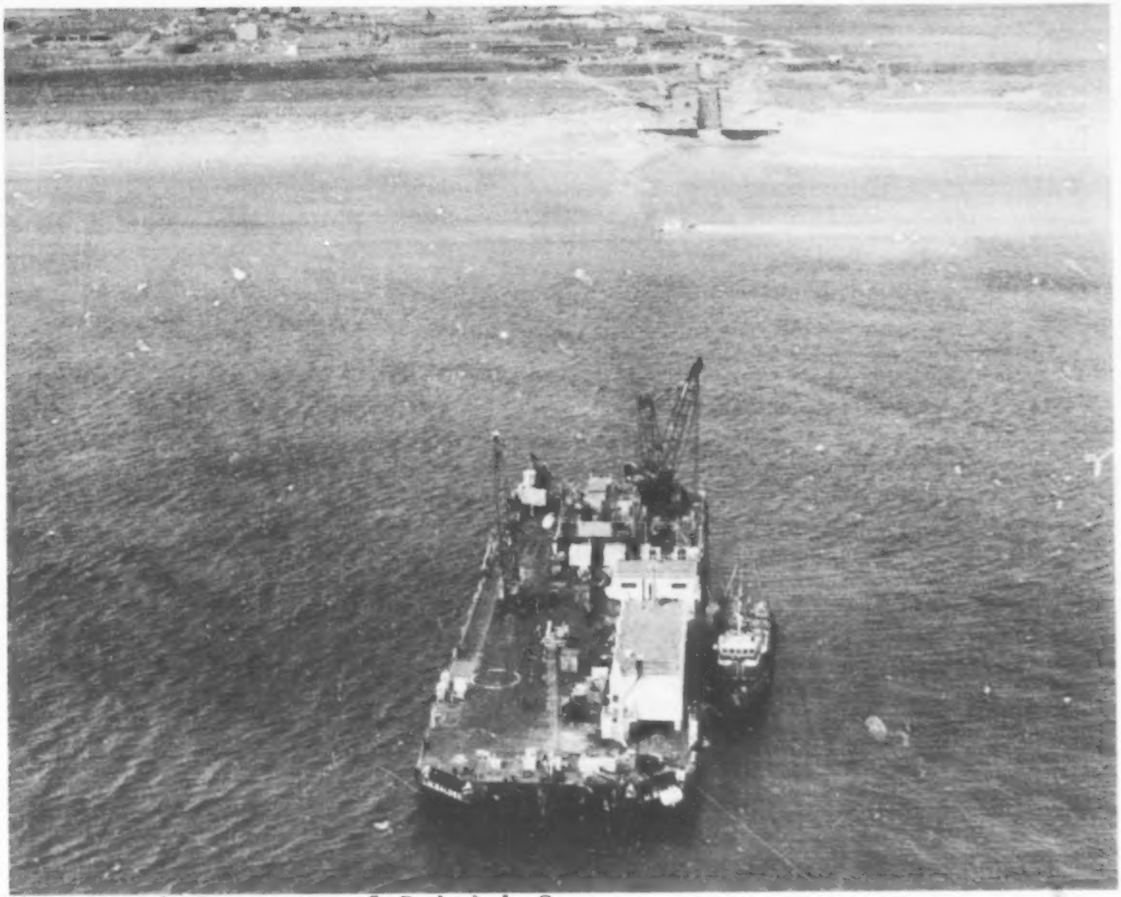
* Gabions are hollow cages of metal mesh filled with earth or stone. A gabion mattress is a group of gabions.

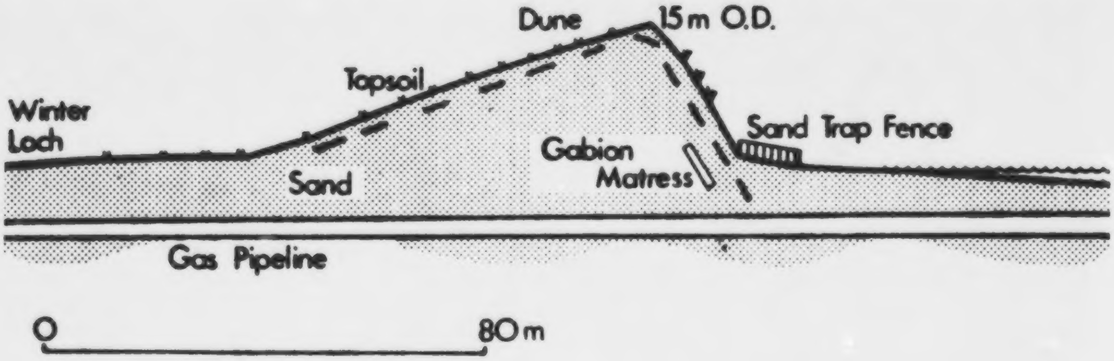


Photograph Courtesy of British Gas.

FIGURE 70. Trenching the Frigg Pipelines in the Nearshore. (Trenching machine can be seen in upper middle of photograph.)

The trench through the loch was refilled, rolled and covered with five to ten centimeters (2-4") of topsoil enriched with fertilizer and lime. Grass seed was sown on the topsoil. A similar treatment was used to remove all evidence of roads and paths used for construction.

Postconstruction surveys of vegetation were conducted at regular intervals following restoration. Replanting of vegetation was determined to be successful based on the criterion of a survival rate of over 50 percent of the plants. Surveys performed by the University of Aberdeen following the "FLAGS" landfall construction in 1976 characterize the landfall area as "having been restored to a form that is comparable with the surrounding areas and, in time, should develop an increasingly natural appearance" (Ritchie et al., 1978).



Source: Ritchie, 1980.

FIGURE 71. Restored Dune at St. Fergus.

At the present time, a comprehensive management and landscaping plan exists for the natural areas around the St. Fergus gas complex which provides for the restoration or improvement of the appearance of the area with any further development. Figure 72 shows the appearance of the landfall just after restoration.*

SULLOM VOE, SHETLAND ISLANDS** (rock outcrops, cobble beaches, agricultural land)

On behalf of a consortium of companies, British Petroleum constructed a 36-inch diameter crude oil pipeline from the Ninian Field in the North Sea that reaches land at Grut Wick in the Shetland Islands. The land portion of this crude oil pipeline system makes an underwater crossing between Cull Ness and Firth Ness before reaching its final destination at the Sullom Voe oil terminal. Landfall construction at Grut Wick took place in the summer of 1976, with the pipeline pull taking place in September 1976, and the trenching of the underwater portions of the line occurring the following spring.

The Setting

Grut Wick is located in the Shetland Islands, northeast of Scotland (Figure 73). The landfall is situated on a small pocket beach made up of shingle and silty sand surrounded by rock outcrops. The beach faces northeast and is subject to occasional wave attack from storms.

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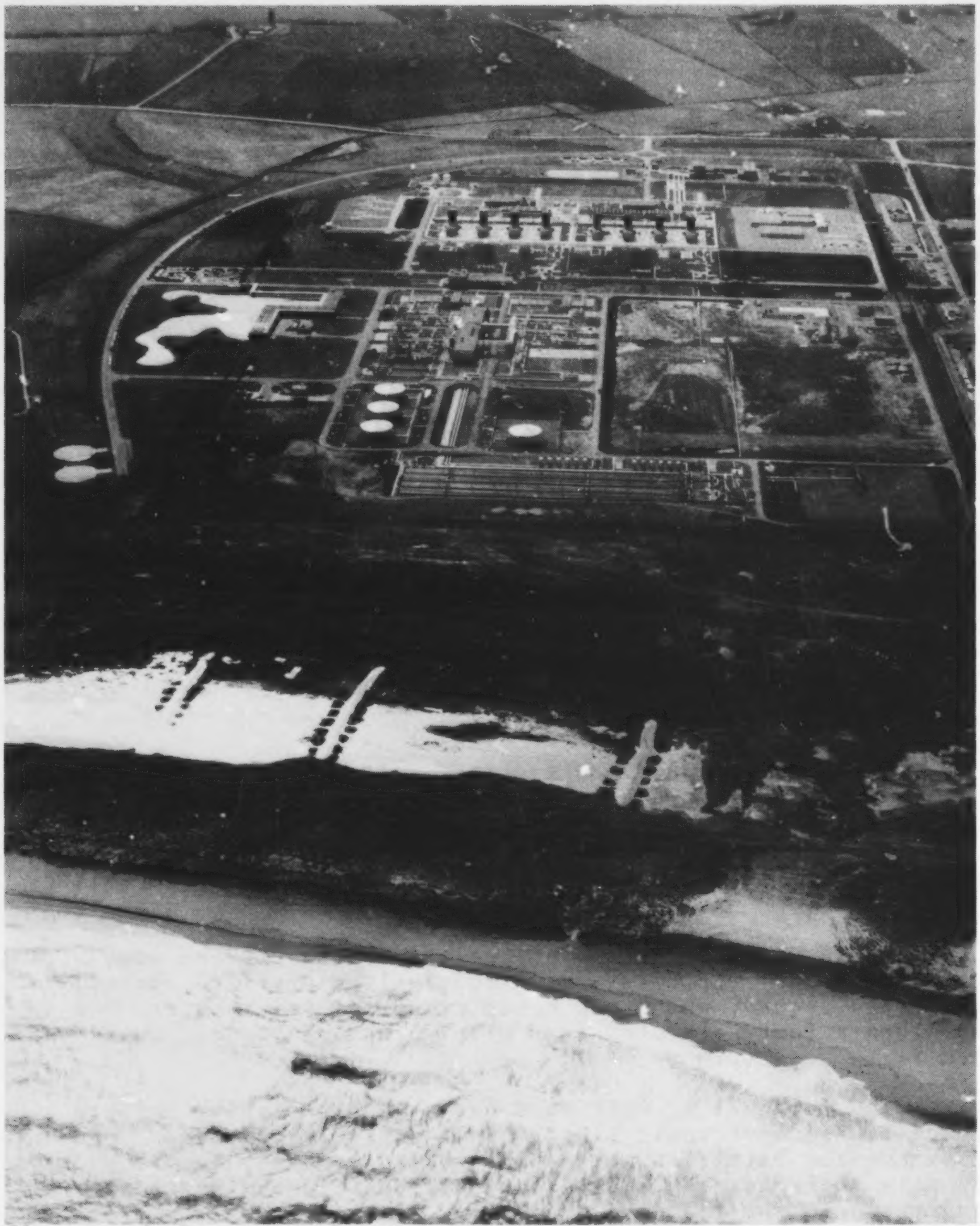
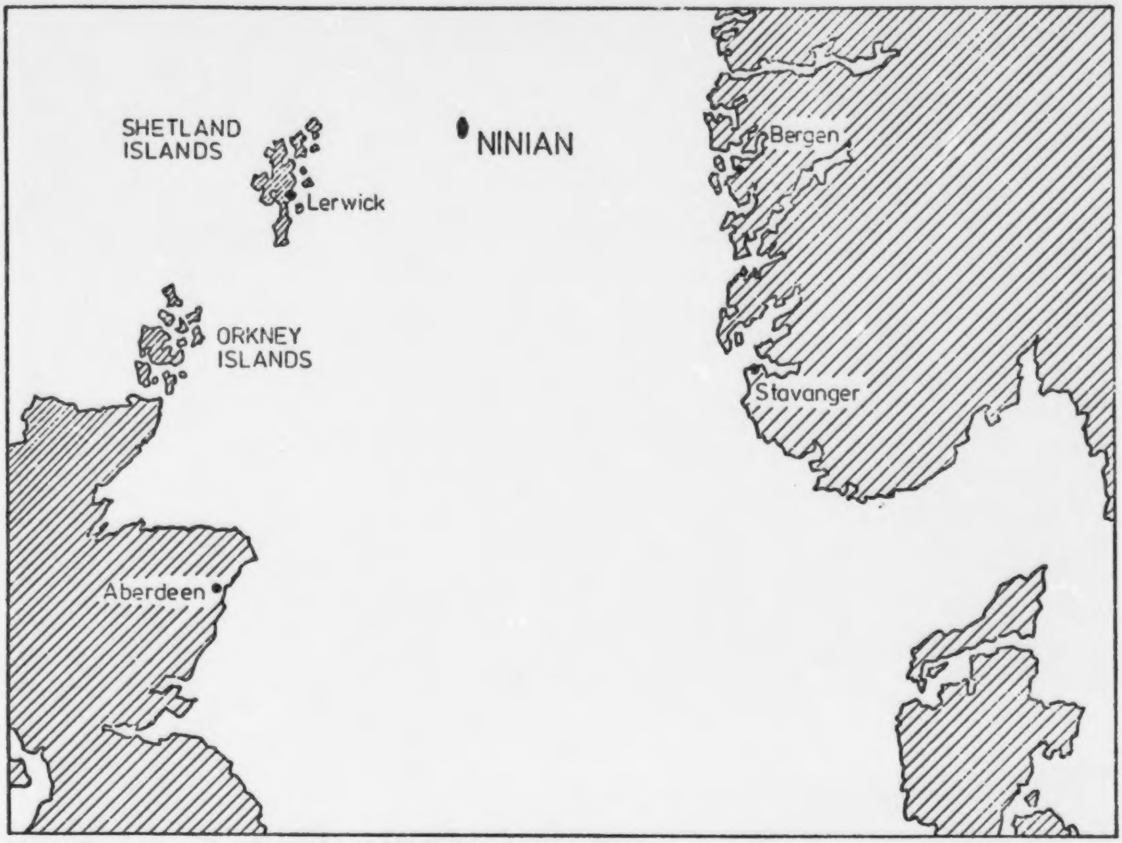
* Figures illustrating the "FLAGS" landfall in Section 5 show the appearance of the Frigg landfall restoration in 1977.

** Primary source of information: F.G. Payne, (BP Trading, Ltd., Middlesex, England) 1979: personal communication.



Photograph Courtesy of British Gas.

FIGURE 72. The St. Fergus Landfall (lower right) after Construction -- early 1976. The trenches seen in the loch were from World War II and were designed to prevent sea plane landings.



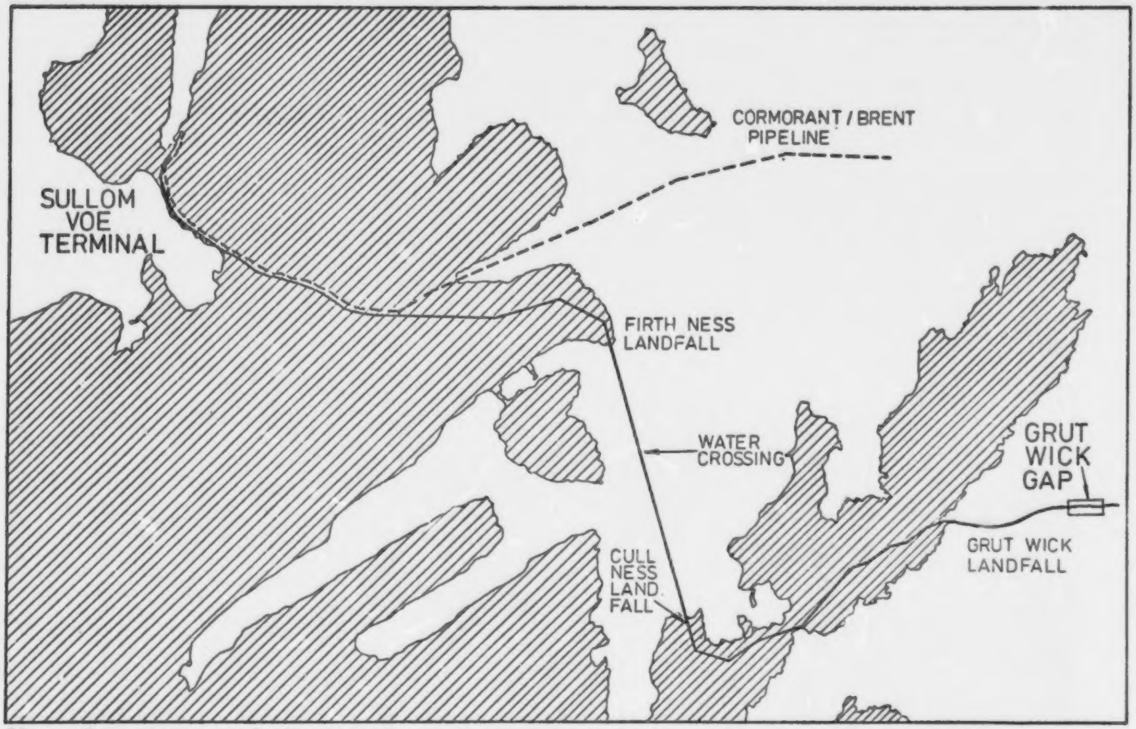
Map Courtesy of British Petroleum.

FIGURE 73. Location of Ninian Field and the Shetland Islands.

There were two possible pipeline routes between Grut Wick and Sullom Voe; the first was a fairly long overland route, while the second, which was finally chosen, was shorter, but involved a four kilometer (2.5 mile) crossing between Cull Ness and Firth Ness (Figure 74).

The landfall at Cull Ness has a gently sloping shingle beach backed by a small (less than two feat high) peat embankment. Firth Ness also has a shingle beach, but is backed by more rocky terrain. Both landfalls have a sediment depth of under two meters (about 6.5 feet).

The land adjacent to all three landfalls is largely underdeveloped and devoted primarily to agriculture and grazing. The native soil type is predominantly peat (which compacts easily) with numerous rock outcrops.


SULLOM VOE TERMINAL
CORMORANT / BRENT PIPELINE
FIRTH NESS LANDFALL
WATER CROSSING
GRUT WICK GAP
GRUT WICK LANDFALL
CULL NESS LAND. FALL

Map Courtesy of British Petroleum.

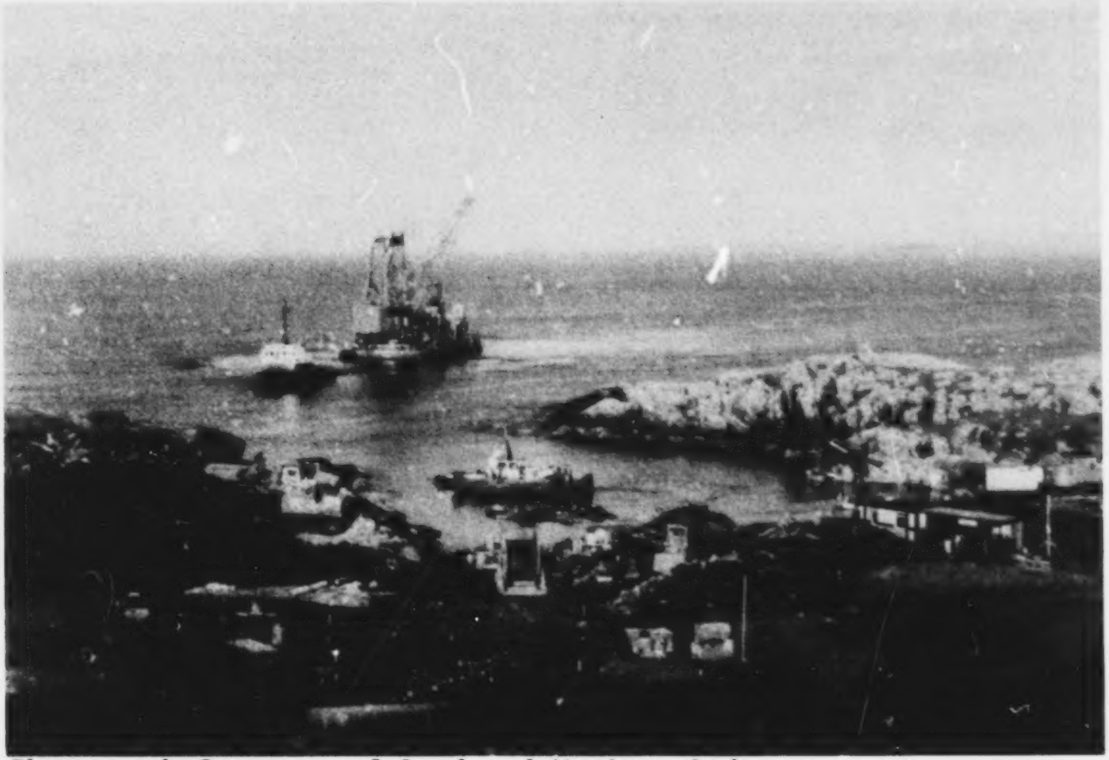
FIGURE 74. Map Showing the Location of the Three Pipeline Landfalls Associated with the Ninian Pipeline. Grut Wick Gap is an opening in the extensive rock outcrops surrounding the Shetland Islands.

The original plan for the offshore pipeline route from Ninian Field was to follow the Cormorant/Brent pipeline. Analysis showed that while following this route was feasible, to do so would cause numerous problems. The Cormorant/Brent pipeline had already required extensive blasting, and depositing and grading stone fill to provide an even bed for the pipeline (NERBC, 1979). Laying a second pipeline along this route would have proved very difficult. While consideration was being given to the joint pipeline route, a gap was found in the extensive bedrock outcroppings surrounding the Shetland Islands allowing the choice of an alternative landfall at Grut Wick.

Construction work in the Shetland Islands required numerous permits or licenses from government agencies including: the Health and Safety Executive; Department of Trade; Technical Arm of the Pipeline Inspectorate of the Department of Energy; and the Department of Agriculture and Fisheries.

Installation

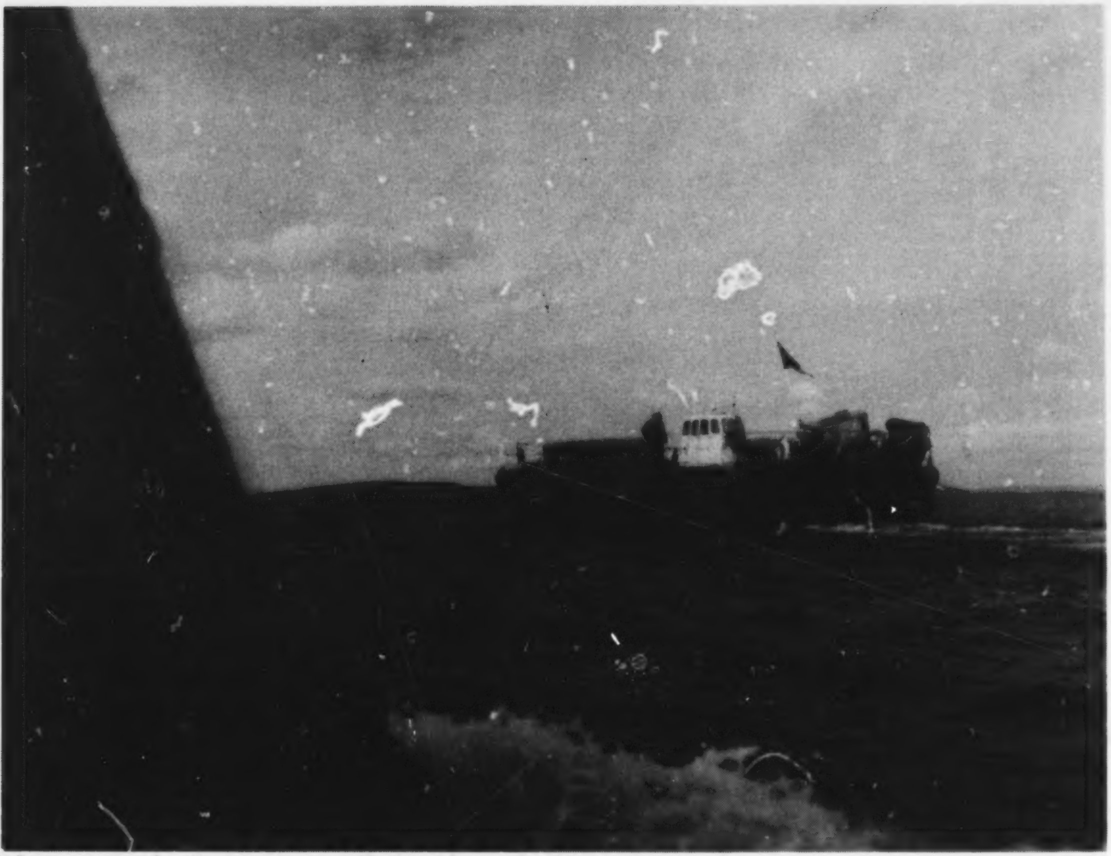
In April 1975, the pipeline trench at Grut Wick was dredged and, where necessary, blasted to provide about four feet of cover for the pipeline (Figure 75). Bedrock in this area was generally less than seven feet beneath the rock and gravel shingle. At Firth and Cull Ness, access was limited to light vehicles only because of narrow roads and peaty soils. An amphibious work craft was used to transport heavy machinery and pipe to the work sites (Figure 76). The access road to the worksites for light vehicles consisted of fine meshed netting laid over the peat with crushed rock placed on the netting. (The net prevented the rock from mixing with the underlying peat.) A winch was set up on shore and lengths of 36-inch diameter pipe with a 3-inch concrete coating were welded on a stationary laybarge offshore and pulled onshore.



Photograph Courtesy of Land and Marine, Ltd.

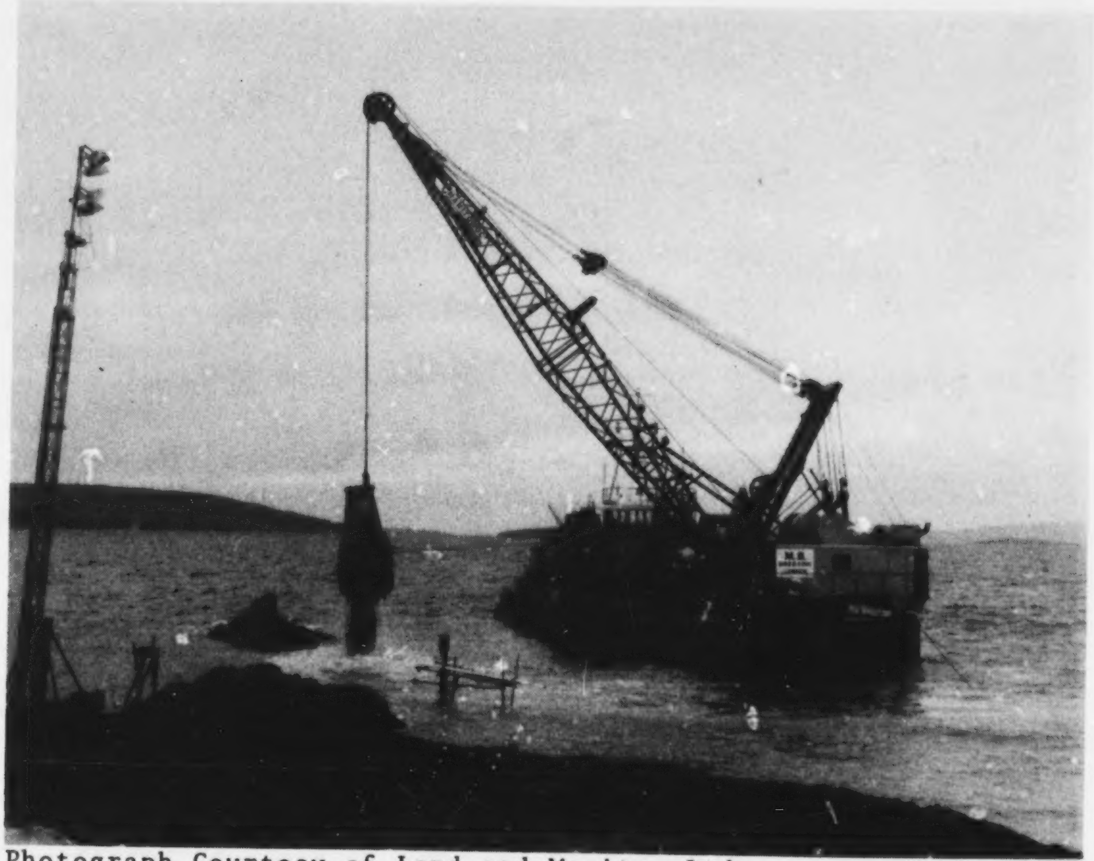
FIGURE 75. Construction at the Grut Wick Landfall.

During the summer of 1976, trenches were prepared at Cull Ness and Firth Ness using a clamshell dredge (Figure 77). Some



Photograph Courtesy of Land and Marine, Ltd.

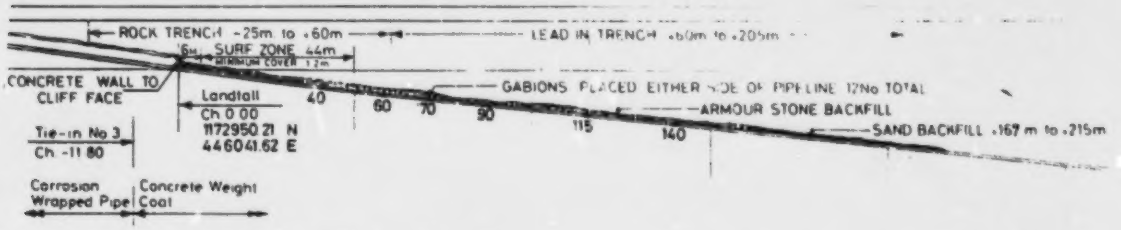
FIGURE 76. Amphibious Work Craft Used for Transporting Heavy Equipment and Pipe.



Photograph Courtesy of Land and Marine, Ltd.

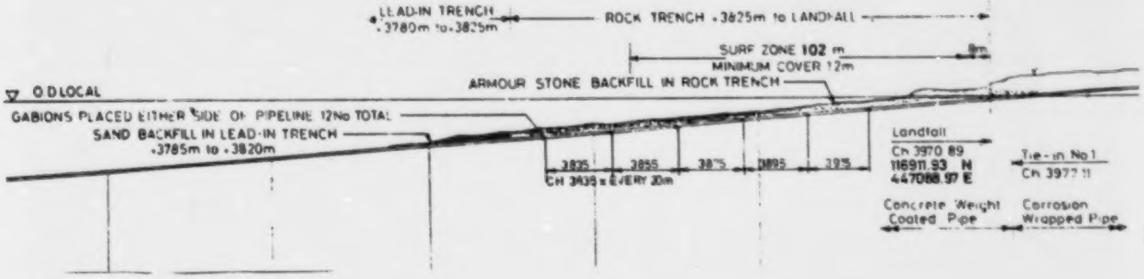
FIGURE 77. Dredging Shore Approach at Cull Ness. Rocky seabed was previously drilled and blasted.

of the 150 meters (490 feet) at either side of the crossing. Gabions were placed on either side of the pipeline trench at both landfalls to limit siltation of the trench (Figures 78 and 79). A trench was not initially cut across the underwater portions of the route except through a small ridge about halfway across the strait and at the shore approaches. Sections of 36-inch diameter pipe with a 3-inch concrete coating were welded at a work site prepared at Cull Ness (Figure 80) and pulled across by two 200 ton winches installed at Firth Ness (Figure 81). The pull was completed in 10 days from September 7-17, 1976. All underwater sections of the pipeline were trenched by jetting in the spring of 1977.


ROCK TRENCH -25m to +60m
LEAD IN TRENCH +60m to +205m
6m
SURF ZONE 44m
MINIMUM COVER 1.2m
CONCRETE WALL TO CLIFF FACE
Landfall
Ch 0.00
1172950.21 N
446041.62 E
Tie-in No 3
Ch -11.80
40
60
70
90
115
140
GABIONS PLACED EITHER SIDE OF PIPELINE 12No TOTAL
ARMOUR STONE BACKFILL
SAND BACKFILL +167 m to +215m
Corrosion Wrapped Pipe
Concrete Weight Coat

Courtesy of British Petroleum.

FIGURE 78. Cross-Section of Firth Ness Landfall Showing Pipeline Placement.

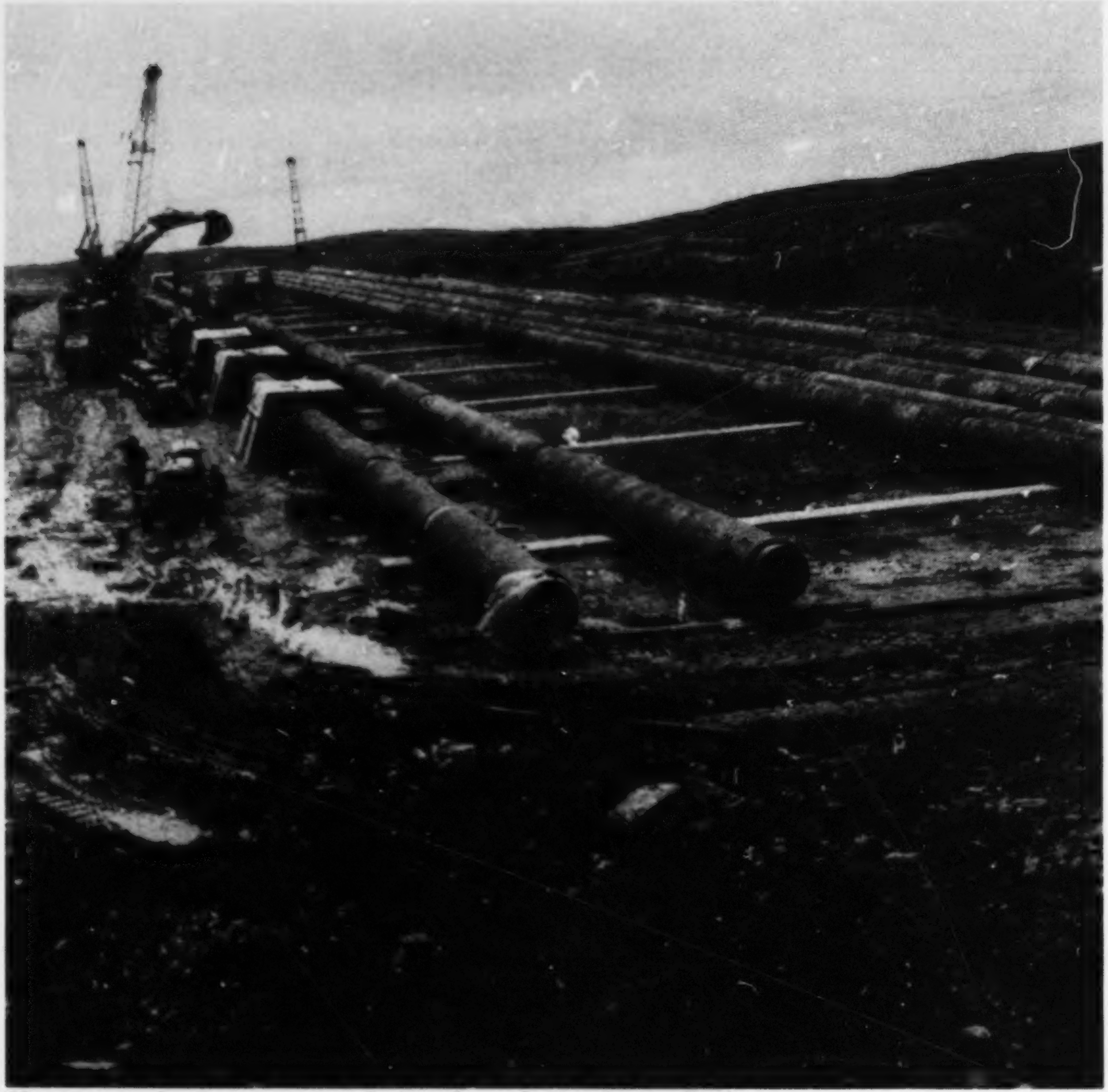

LEAD-IN TRENCH +3780m to +3825m
ROCK TRENCH +3825m to LANDFALL
SURF ZONE 102 m
8m
MINIMUM COVER 1.2m
ARMOUR STONE BACKFILL IN ROCK TRENCH
O.D.LOCAL
GABIONS PLACED EITHER SIDE OF PIPELINE 12No TOTAL
SAND BACKFILL IN LEAD-IN TRENCH +3785m to +3820m
3835
3855
3875
3895
3915
CH 3835 + EVERY 20m
Landfall
Ch 3970.89
116911.93 N
447088.97 E
Tie-in No 1
Ch 3977.11
Concrete Weight Coated Pipe
Corrosion Wrapped Pipe

Courtesy British Petroleum.

FIGURE 79. Cross-Section of Cull Ness Landfall Showing Pipeline Placement.

Restoration

All three pipeline landfalls' trenches were refilled using armour stone -- cubical-shaped stone ranging in size from 150 to 500 millimeters (mm) with 80 percent greater than 300mm. On top of the armour stone, a layer of rockfill and shingle,



Photograph Courtesy of Land and Marine, Ltd.

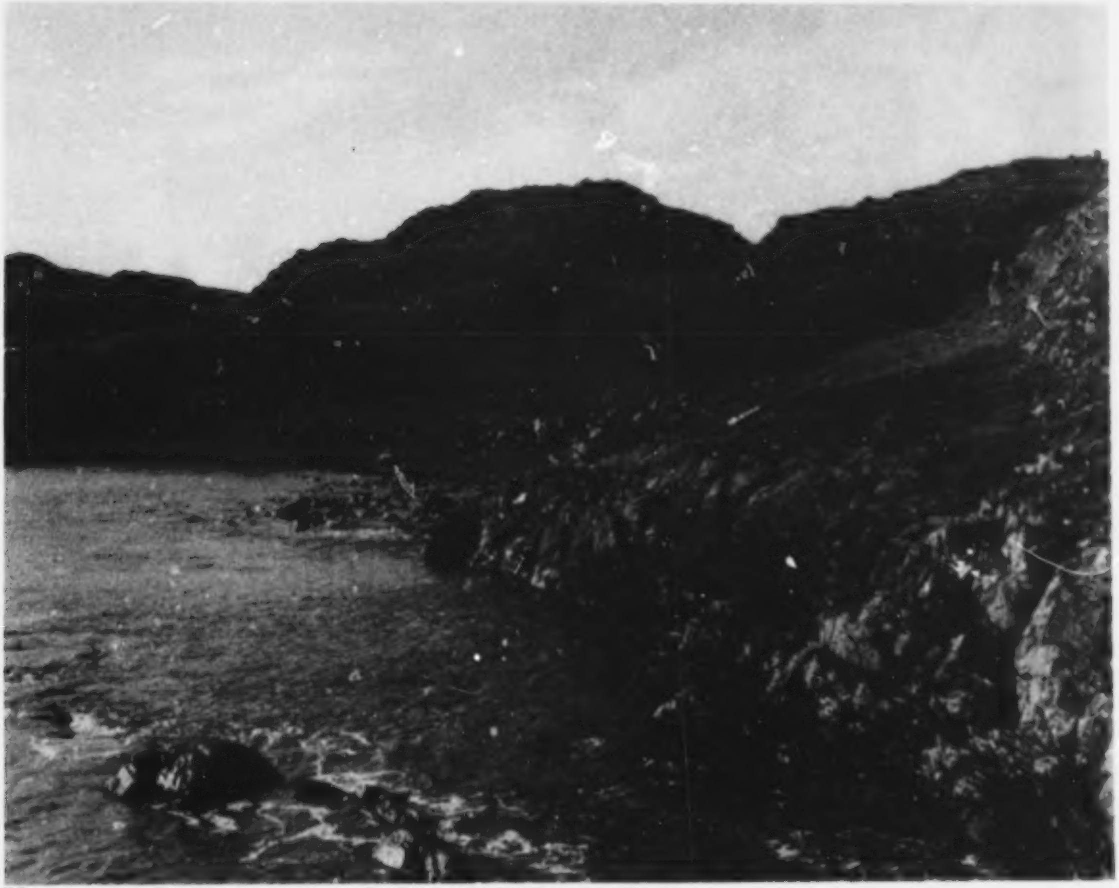
FIGURE 80. Pipe Welding Site at Cull Ness.

Photograph Courtesy of Land and Marine, Ltd.

FIGURE 81. Two 200-Ton Winches for Pipeline Pull Installed at Firth Ness.

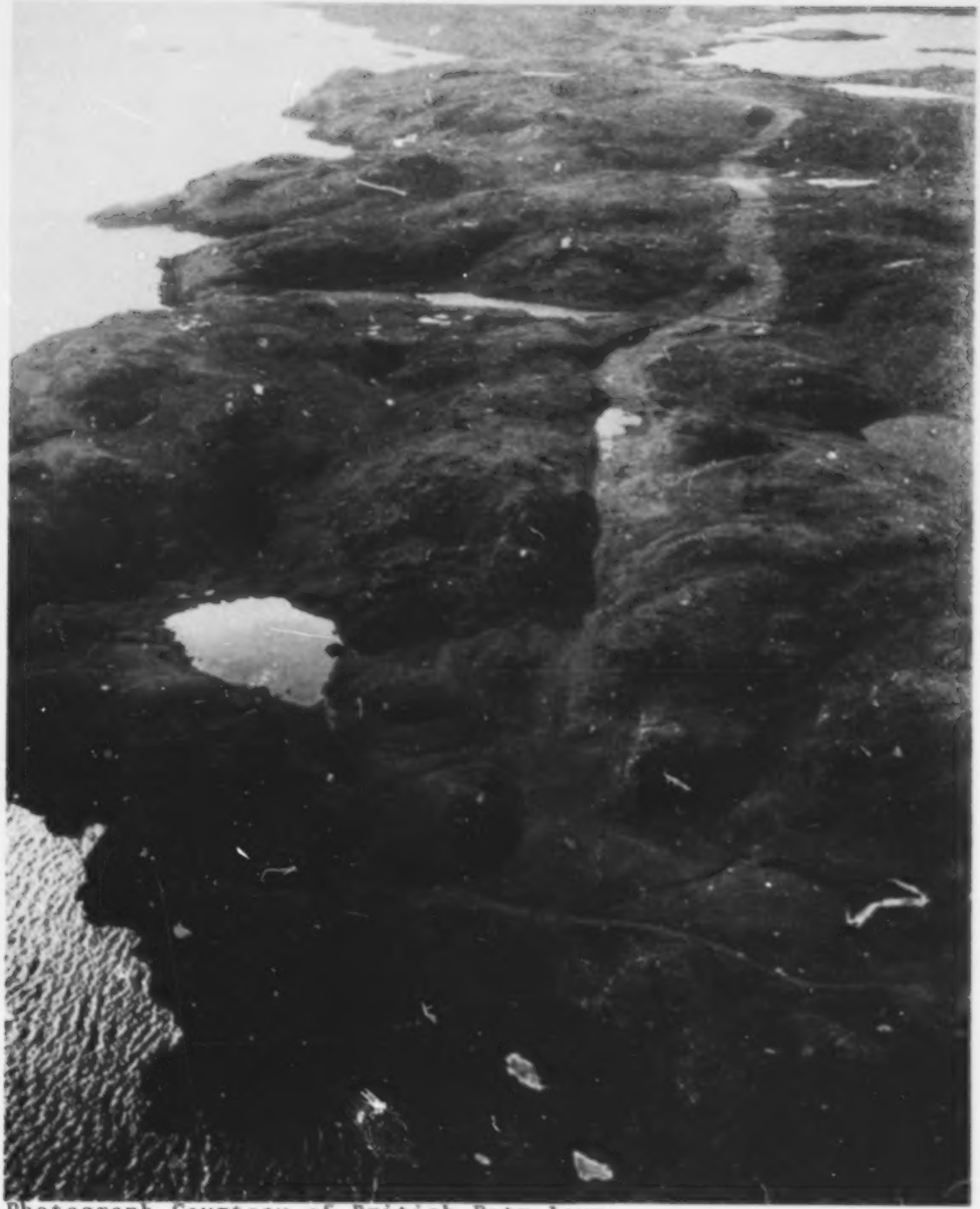
approximating the natural beach material in size and diameter, was added. At the work sites, topography was restored to original condition and at Grut Wick, new drainage channels were cut to limit erosion. It was necessary to restore a small rock cliff at the Firth Ness site using concrete and gabions.

The sites were covered with peat which was fertilized and reseeded. Restoration work at the sites was considered as constituting an agricultural improvement, not a return to their original conditions, and was, therefore, not subject to the acquisition of planning permission from local authorities. Figures 82 through 85 show the appearance of the landfalls and adjacent areas in fall 1978, three years after construction.



Photograph Courtesy of British Petroleum.

FIGURE 82. Landfall at Grut Wick, November 1978. Note the sheep grazing on the revegetated slope.



Photograph Courtesy of British Petroleum.

FIGURE 83. Aerial View of the Grut Wick Landfall, October 1978.

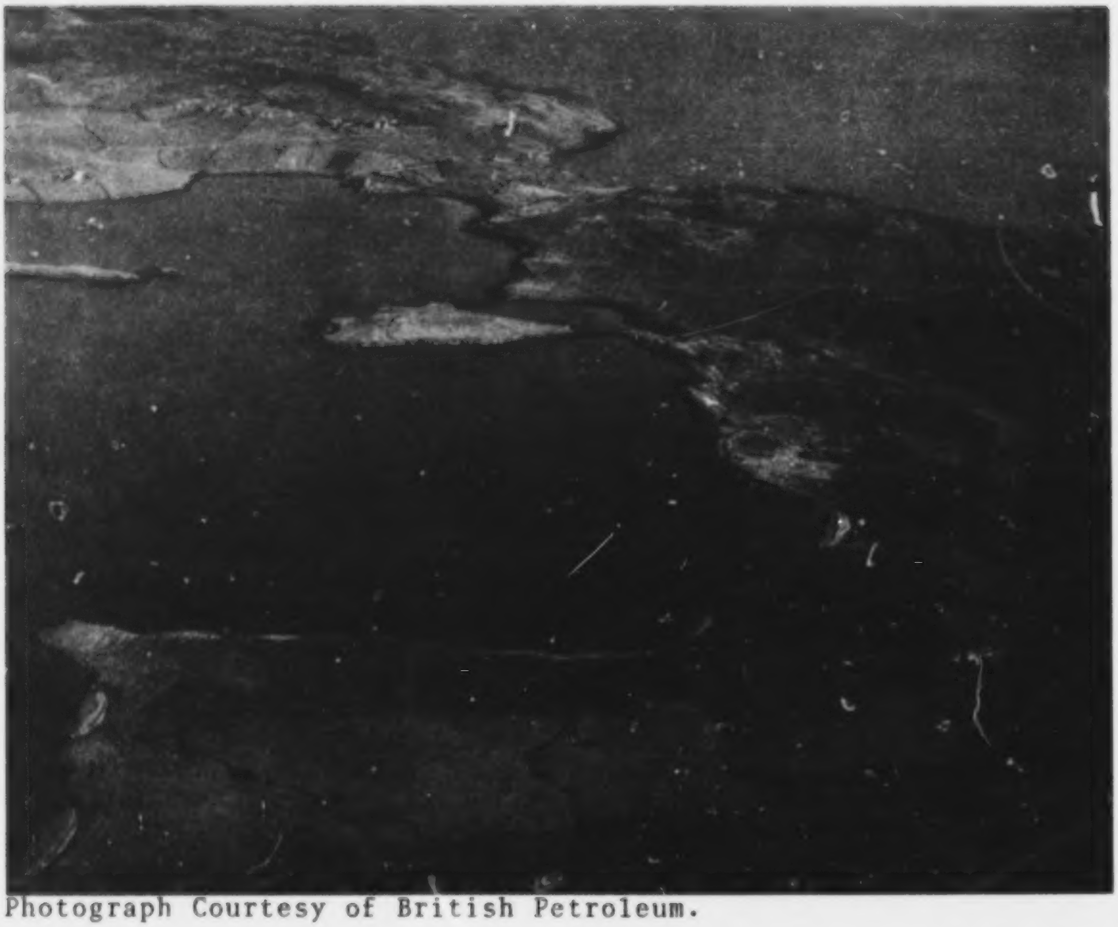
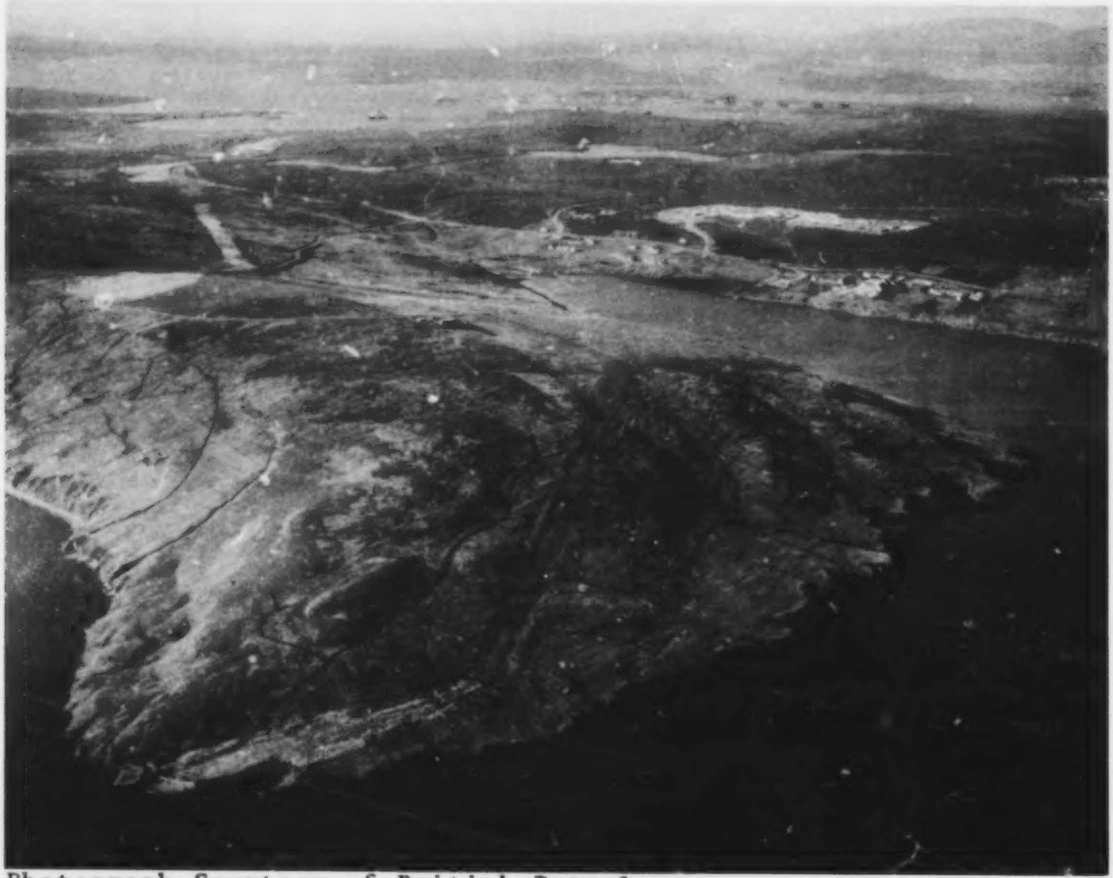

Photograph Courtesy of British Petroleum.

FIGURE 84. The Cull Ness Landfall and Work Site, October 1978. Pipe was welded on the broad, grassy area in the lower portion of the picture. The landfall is at the lower left hand corner.



Photograph Courtesy of British Petroleum.

FIGURE 85. Landfall Site at Firth Ness. The landfall for the Comorant/Brent pipeline is at the end of the small body of water in the right center. Sullom Voe terminal is visible at upper right.

AMLWCH, WALES* (rock cliff)

The town of Amlwch on the island of Anglesey, Wales (Figure 86) is the site of a landfall for twin 40-inch diameter crude oil pipelines from an offshore single buoy mooring (SBM) to the Anglesey marine terminal onshore, and a 24-inch diameter line for bunker fuel delivery offshore. Landfall construction activities occurred over two working seasons (April to September) beginning in 1973.

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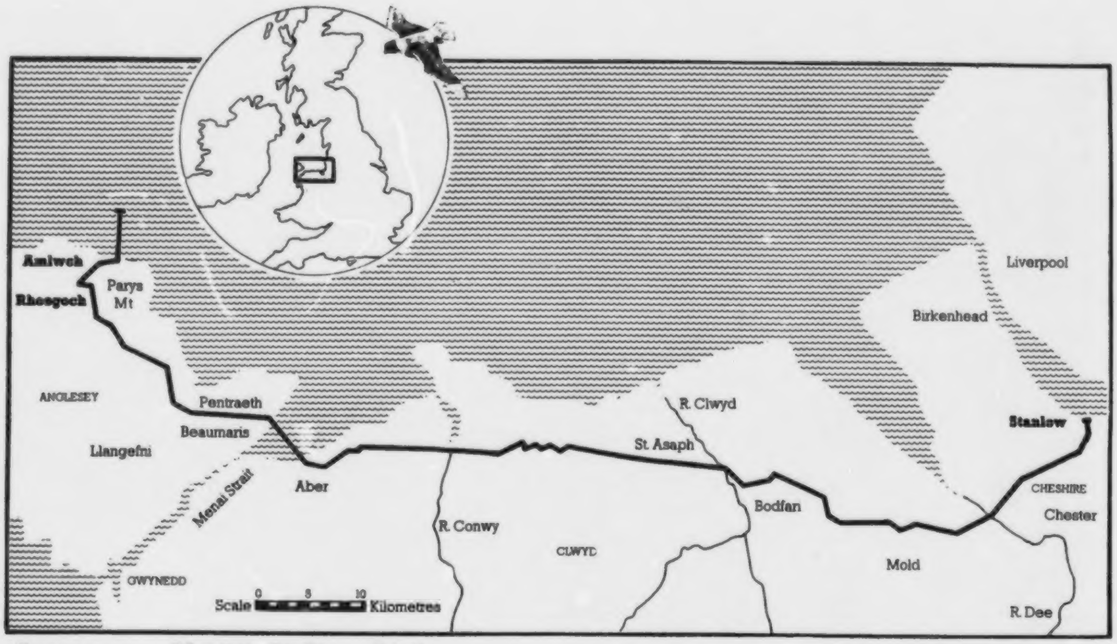
* Primary source of information: William Binger, (LOOP, Inc., Harvey, Louisiana) 1979: personal communication.


Amlwch
Rhosgoch
Parys Mt
ANGLESEY
Pentraeth
Beaumaris
Llangefni
Menai Strait
Aber
GWYNEDD
Scale 0 5 10 Kilometres
R. Conwy
CLWYD
R. Clwyd
St. Asaph
Bodfan
Mold
Liverpool
Birkenhead
Stanlow
CHESHIRE
Chester
R. Dee

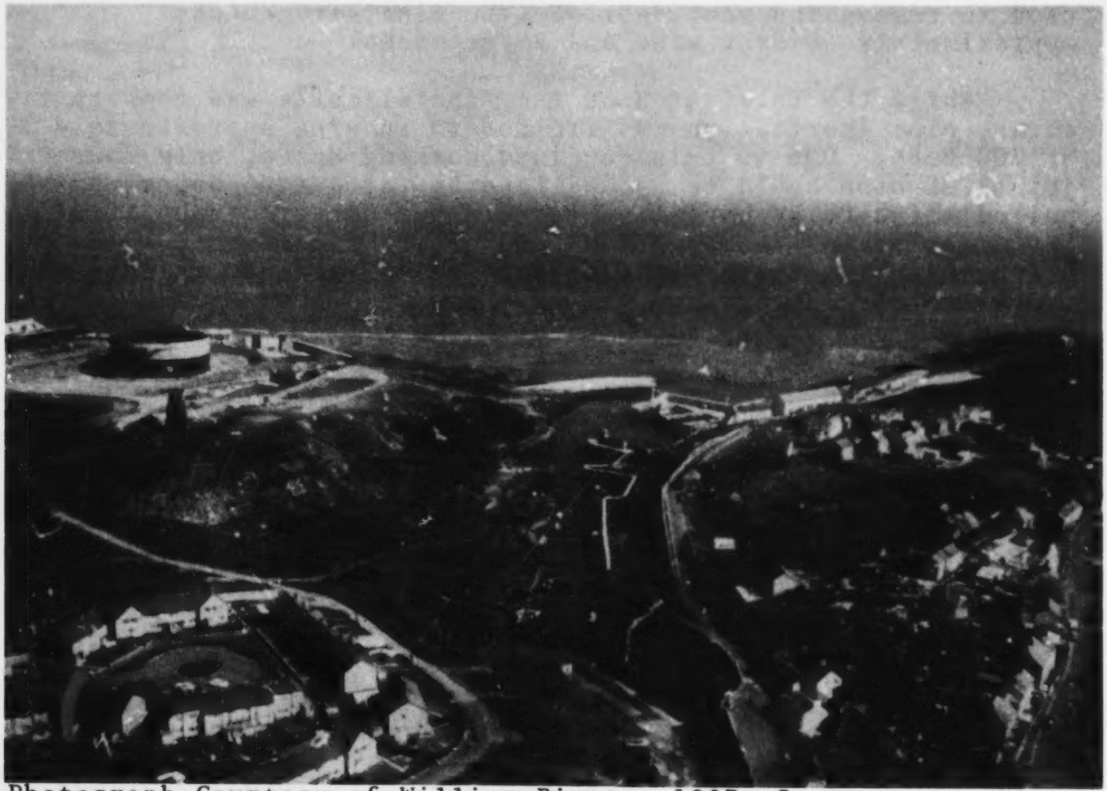
Source: Shell U.K., Ltd.

FIGURE 86. Map Showing the Anglesey Marine Terminal Pipeline System.

The Setting

The shoreline and offshore regions near the town of Amlwch are extremely rocky. The tidal range in the area can be as much as 24 feet with strong currents parallel to the coast. Adjacent to the landfall site is Amlwch's inner harbor which had been a busy seaport in the last century (Figure 87); however, use of the harbor is presently limited to small boats.

The oil landed at Amlwch is transported by two 40-inch diameter pipelines overland some three miles to a storage terminal in Rhosgoch. From this terminal, a single 36-inch diameter land pipeline transports the oil to Shell's refinery in Stanlow, 80 miles to the east. The land pipeline encounters a major water crossing at the Menai Straits from the island of Anglesey to mainland Wales. (This crossing is discussed separately in this chapter.) The decision to build the pipeline from Amlwch to Stanlow was based primarily on the suitability of the Amlwch location for an offshore buoy mooring and the reasonable distance to Stanlow. One of the major problems encountered in Wales was convincing the local population that the landscape could be restored to its original conditions. The developer addressed this concern by working with the various



Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 87. View of Landfall Site (upper left) and the Harbor and town of Amlwch. The tank is for the storage of bunker fuel.

planning agencies, landowners' associations, and farmers' unions to reach agreements on working practices, land easements and compensation payments along the land route of the pipeline.

Preconstruction surveys of the proposed route included: borings to determine the nature of rock and soil conditions, current surveys in the offshore areas, and marine surveys (by the University of Bangor) to monitor changes in plant and animal populations both offshore and at shoreline.

Installation

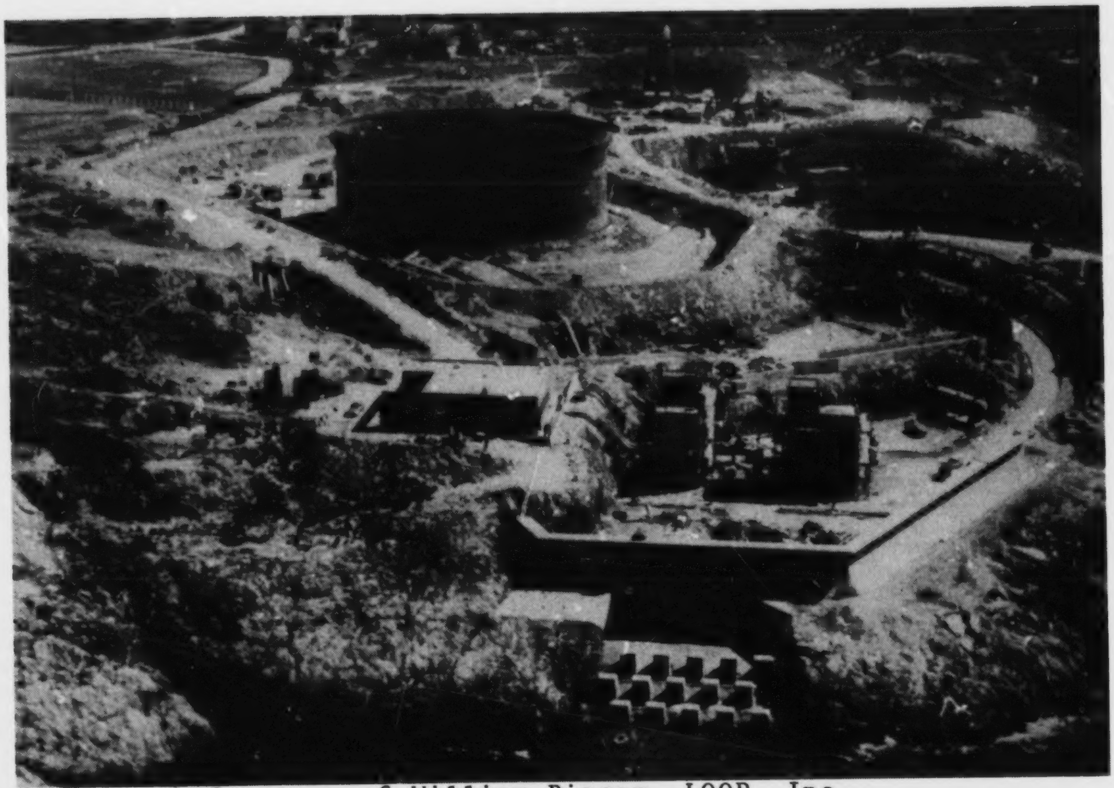
Construction activities began in 1973 with the excavation of the pipeline trench at the shoreline. Because the shoreline is rock, it was necessary to use excavation techniques including blasting. The first 300 meters (1000 feet) of trench offshore was also solid rock and required blasting. A bucket dredge was used to remove the rock debris. The final trench was approximately 80 feet wide and 7 feet deep.

While the total area of the landfall site was four to five acres, pipe fabrication was limited to an area approximately 100 by 200 feet. Due to this confined working space, only four joints of pipe could be welded together at a time before being pulled offshore by barge-mounted winches anchored approximately 1500 feet beyond the projected end of the pipeline (2 miles offshore). The three separate pipe pulls were accomplished in approximately one month.

Restoration

Restoring the landfall site to its original condition would have been next to impossible because of the extensive blasting and removal of bedrock during construction. Further, it was necessary to build a booster (pumping) station and bunker fuel storage tank on the landfall site; therefore, restoration work was designed primarily to provide adequate protection for the pipeline and the shore facilities.

A seawall was built across the trench and concrete was laid over the pipeline in the trench to a point about 300 feet seaward of the low water line. Concrete "teeth" (Figure 88) -- used to break up waves moving up this concrete slope -- were built from the low water line to just above the high water line. The pipeline trench landward of the landfall site was restored and replanted; vegetation took hold after about one year. Hedges and trees were used to help shield the shore facilities from sight. Special attention was given to the storage tank which was painted with colors specifically chosen to minimize the visual impact. The Amlwch terminal has recently been awarded a Royal Institute of Britain Architects Citation for excellence in design, particularly for the favorable environmental effect of the terminal facilities on the countryside.



Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 88. The Landfall Site at Amlwch. Concrete "teeth" in the lower, center are used to break up waves moving up the concrete-filled pipeline trench.

THE MENAI STRAITS, WALES* (tidal flats; highway)

The Menai Straits is the site of a 36-inch diameter crude oil underwater pipeline crossing between the island of Anglesey and mainland Wales in Great Britain. Construction was started in January 1974 and completed in March 1975. The pipeline pull itself occurred across the Straits in September 1974.

The Setting

The Menai Straits is a body of water separating the island of Anglesey from mainland Wales, approximately 210 miles northwest of London, England (Figure 86). At the pipeline crossing, the Straits are 3.3 miles wide. The first one-half to three-quarters of a mile from the west bank is a shipping channel, while the remainder of the distance contains extensive tidal flats -- the Lavin Sands (Figure 89). The tidal range in

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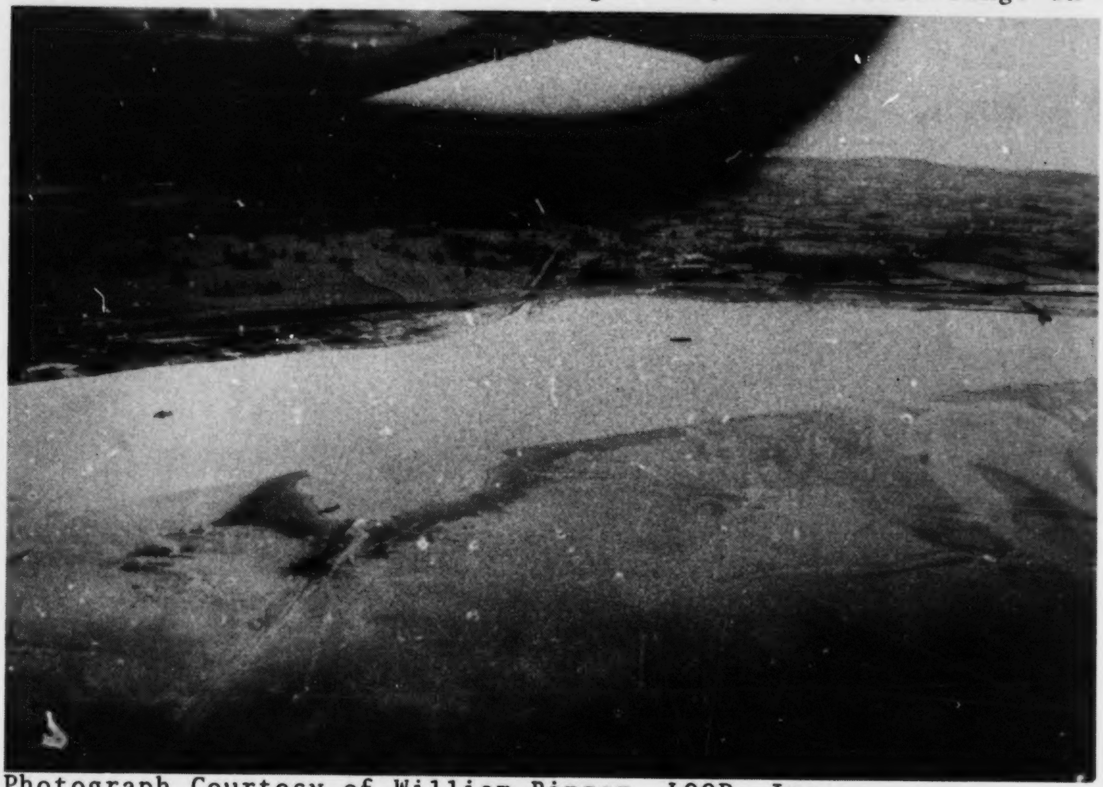
* Primary source of information: William Binger, (LOOP, Inc., Harvey, Louisiana) 1979: personal communication.



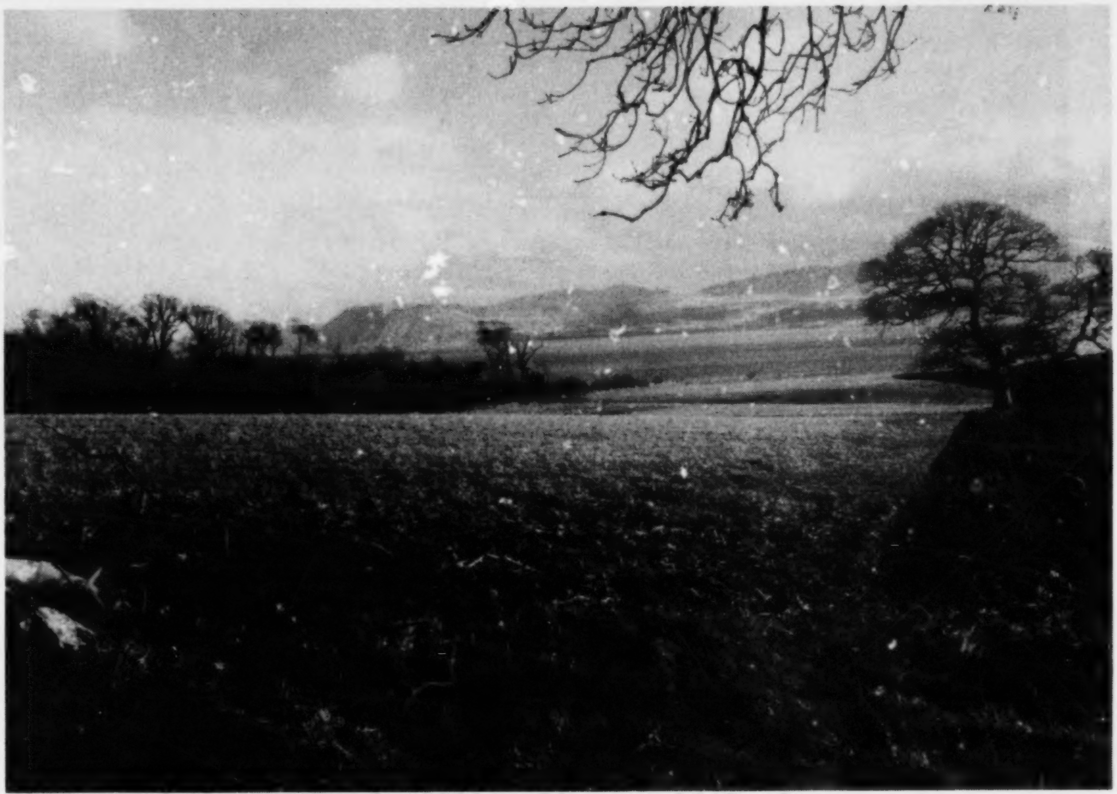
Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 89. Aerial View of Extensive Tidal Flats -- The Lavin Sands -- in the Menai Straits, 1974.

the Menai Straits averages 18-20 feet, exposing most of the Lavin Sands at low tide, and producing swift tidal currents that dominate the water flow through the Straits.

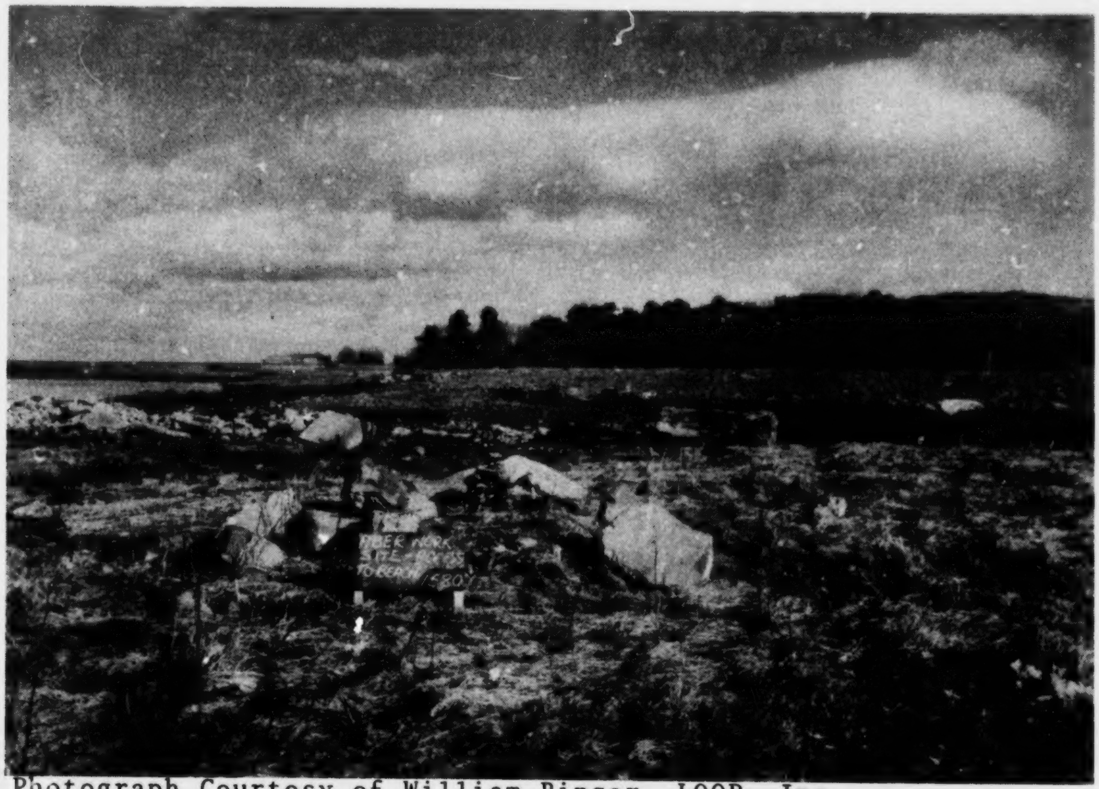
The pipeline crossing the Menai Straits is part of a system that connects the deepwater marine terminal at Amlwch on the north coast of Anglesey to Shell's refinery at Stanlow (80 miles to the east).

Most of the land on either side of the Straits is devoted to agriculture (Figures 90 and 91). Obstacles to construction included: a small highway on the Menai's west bank as well as the extensive tidal flats, the shipping channel, and extreme tidal range within the Straits.



Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 90. Menai Straits Crossing. Work area prior to the beginning of construction, 1973.



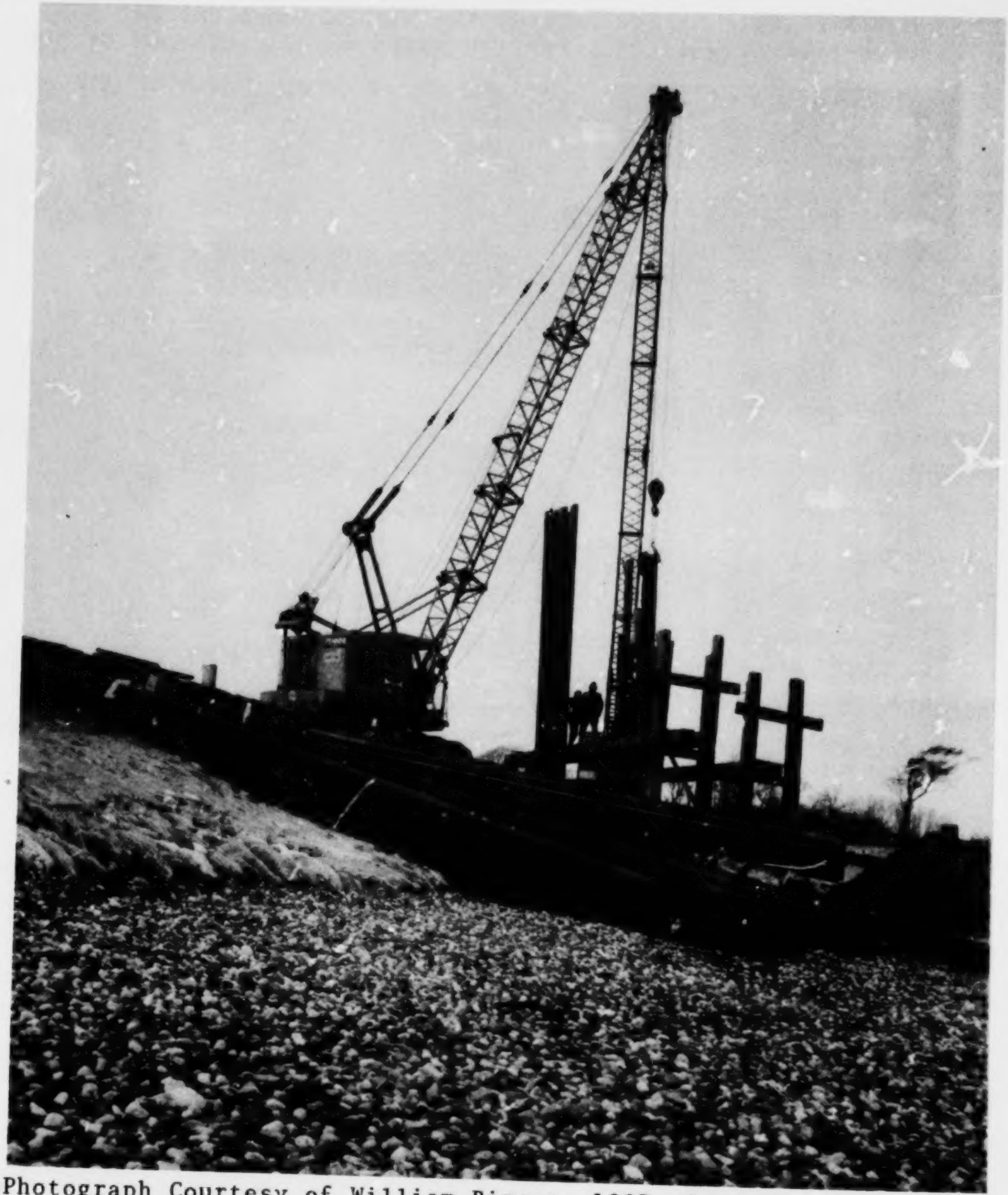
Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 91. View before construction of the work site opposite from the pipeline work site. This site was where the winches used to pull the pipeline across the Straits were located, 1973.

Installation

Work on dredging a trench across the shipping channel began in January, 1974. This trench was 9-10 feet wide and 20 feet deep, providing over 15 feet of cover for the pipe. Dredging was continued into the tidal flats for about 500 feet. This provided deep burial for the pipeline on this portion of the flats and protected it against future scouring action (burial depth on the rest of the flats was 6 feet). Dredged materials were hauled by barge to an underwater dumping area about 3 miles distant to be reclaimed at a later date and used to refill the trench after construction.

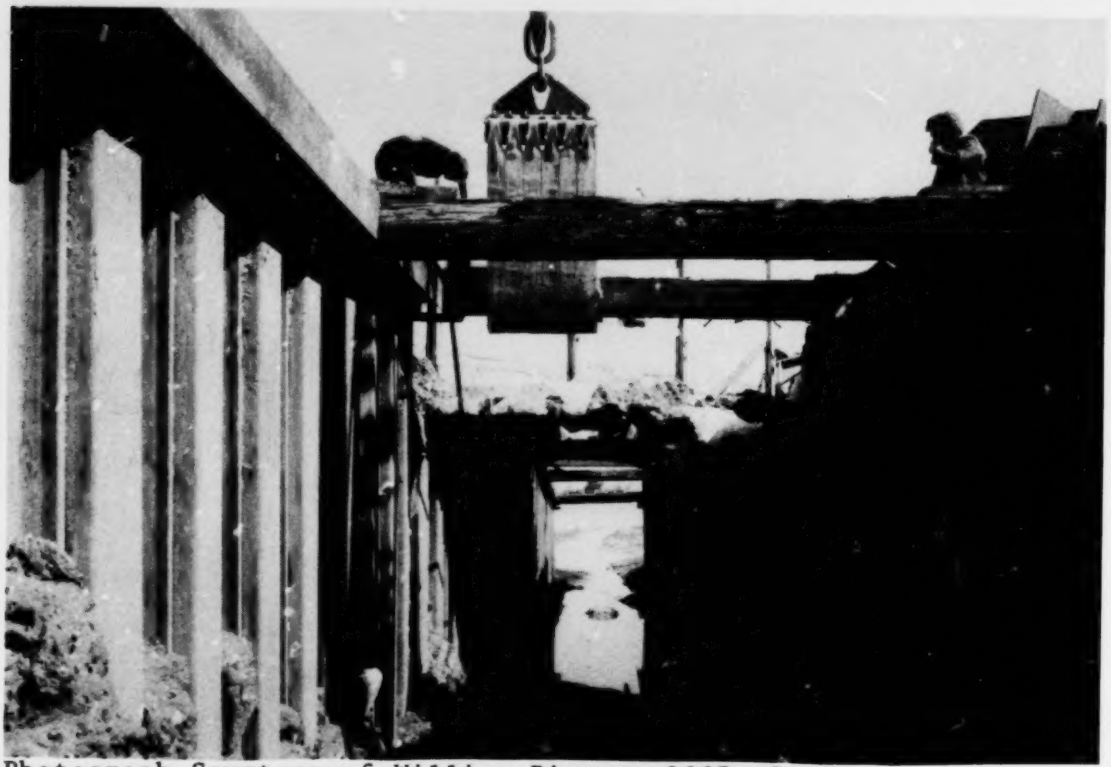
While the channel was being dredged, a worksite was prepared and construction began at the landfalls. Sheet piling was driven at low tide (Figure 92) to provide an opening under the highway on the west side of the Straits. It was necessary



Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 92. View of Beach at Low Tide with Sheet Pile Driving in Background. Sheet piling was driven to provide opening under highway for pipeline, 1974.

to build a small bridge to keep the highway open during construction (Figure 93). On the worksite, 11 sections of pipe

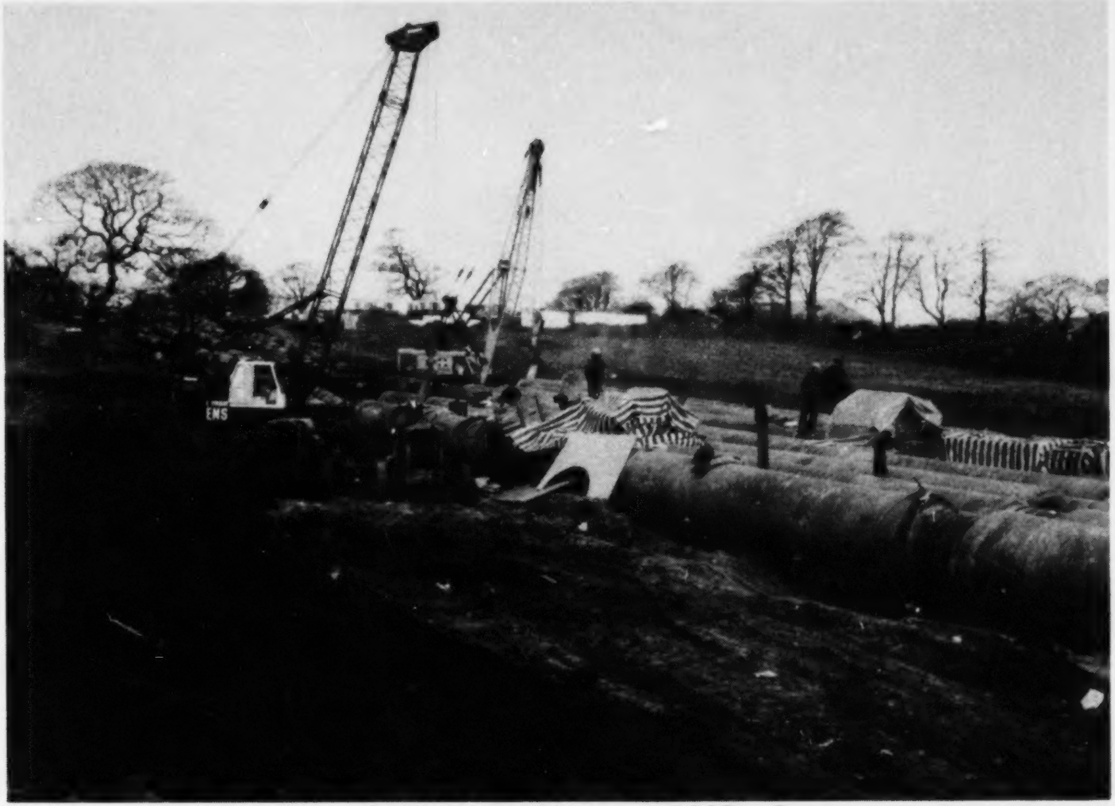


Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 93. Completed Opening Under Highway with Sheet Piling in Place, 1974.

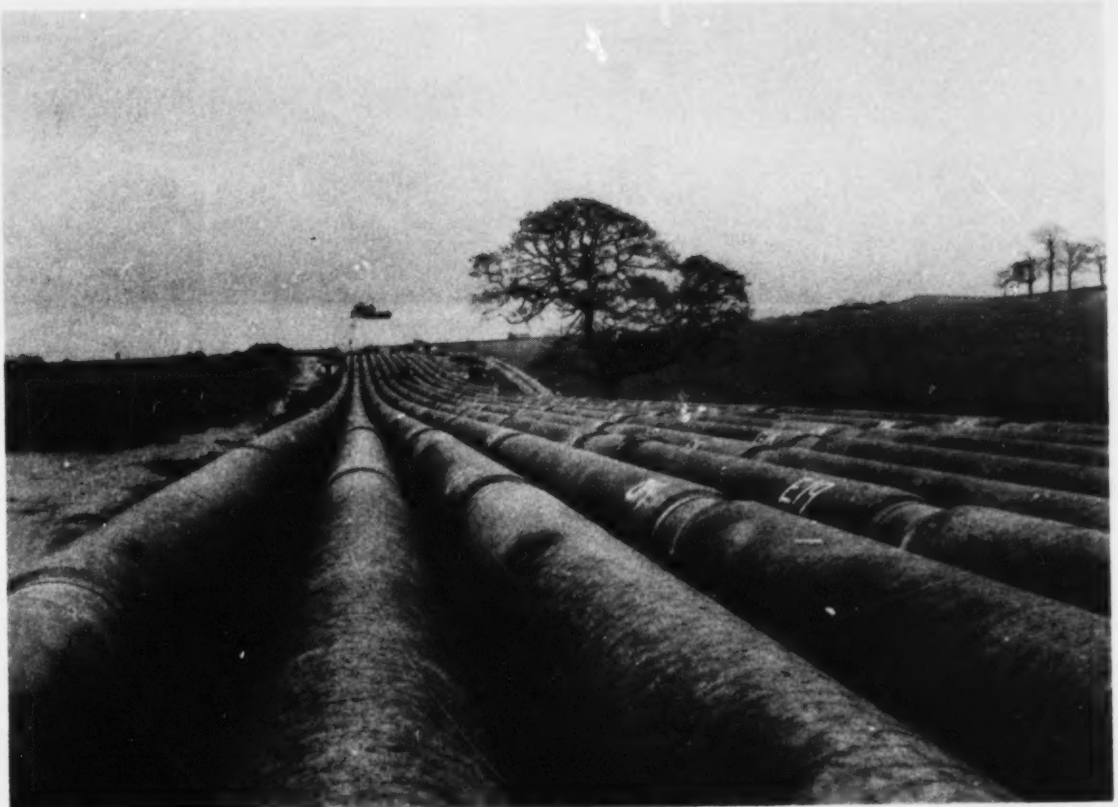
(10 sections of 1670 feet and one of 1066 feet) were "made up" in the following manner: forty-foot sections of 36-inch diameter pipe with three-inch concrete coating were welded together. The joints were then coated with alternate layers of coal tar enamel and fiberglass wrapping and finally filled with concrete (Figure 94 and 95). On the east side of the Straits, four 100-ton capacity winches were installed (Figure 96). Nearly 11 miles of two-inch steel wire cables were required during the pipeline pull. The winches provided an average pulling speed of 13 feet per minute.

The pipeline pull was started in September and was completed in approximately six weeks. Each of the 11 "made-up" sections of pipe was moved into position, welded to the preceeding section, and pulled across the Straits. Pulling was timed to coincide with high tide to provide the water necessary



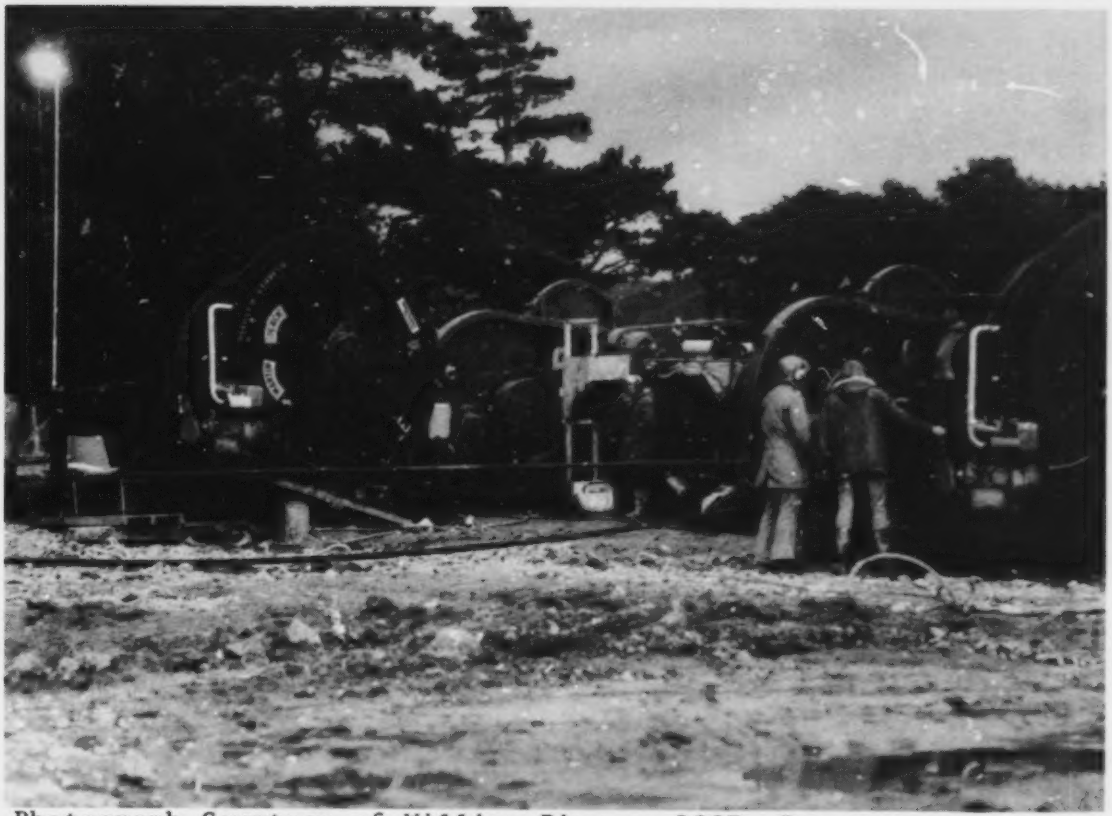
Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 94. Work Site with Pipe, 36" with Concrete Coating to Provide Negative Buoyancy. Pipe is being welded into strings prior to being pulled across the Straits, 1974.



Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 95. View Showing Ten Strings Made Up Prior to Pulling, 1974.

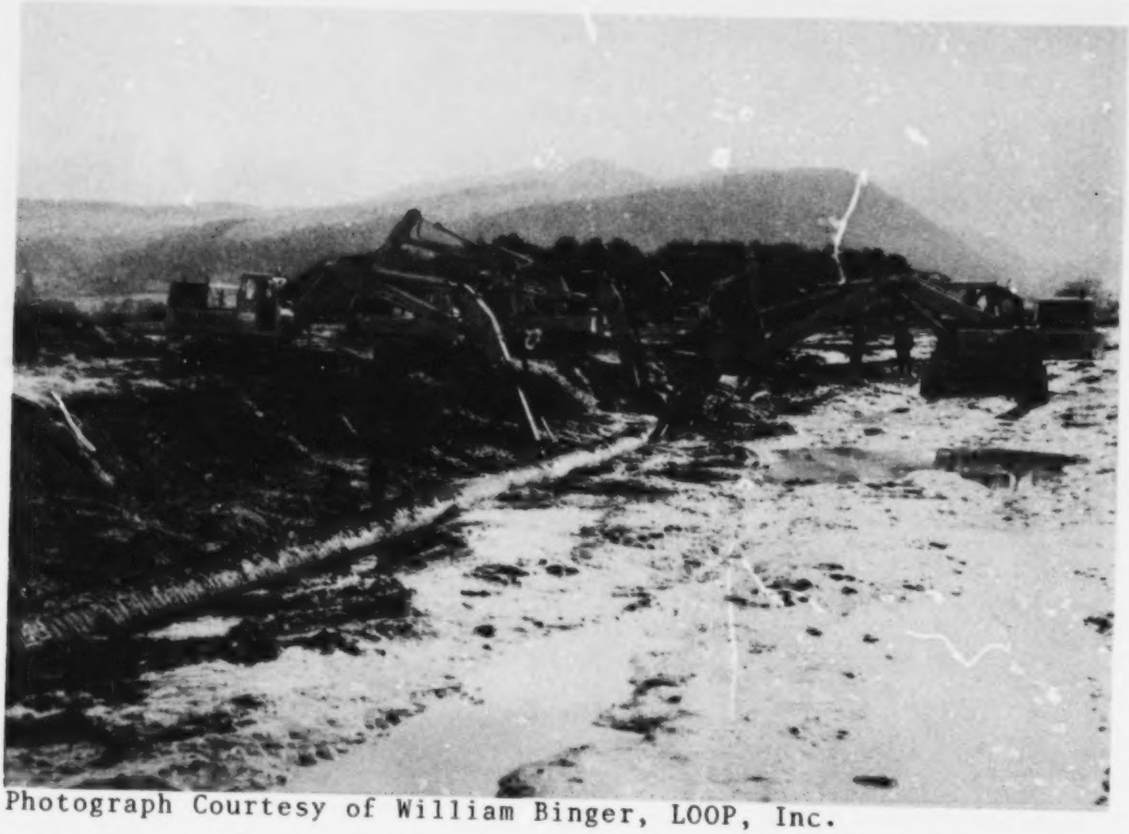


Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 96. Four Winches, 100 Ton Capacity Each, Were Used in Parallel to Pull the Pipe. Two of these winches are shown in the photo.

to facilitate the pull. The tidal cycle allowed about three hours of pulling time twice daily. Floats were attached to the pipeline before pulling, to help reduce friction during the pull.

Following the pull, work began to bury the pipeline. On a portion of the tidal flats, a fluidization unit was used. This unit used jets of water to liquify the sand under the pipeline, allowing the combined weight of the unit and the pipeline to cause the line to sink into the sand. The fluidization unit was pulled along the pipeline by the four winches used during the pipeline pull. Closer to shore, excavators and diggers (Figure 97) were used to trench and bury the pipe during low tide, while pumps helped keep the area relatively free from water. Minimum cover along the pipe was six feet. Deepwater sections of the pipeline trench (in the navigation channel) were buried using the original dredged material. Materials were suction dredged from the temporary underwater storage area and transferred by



Photograph Courtesy of William Binger, LOOP, Inc.

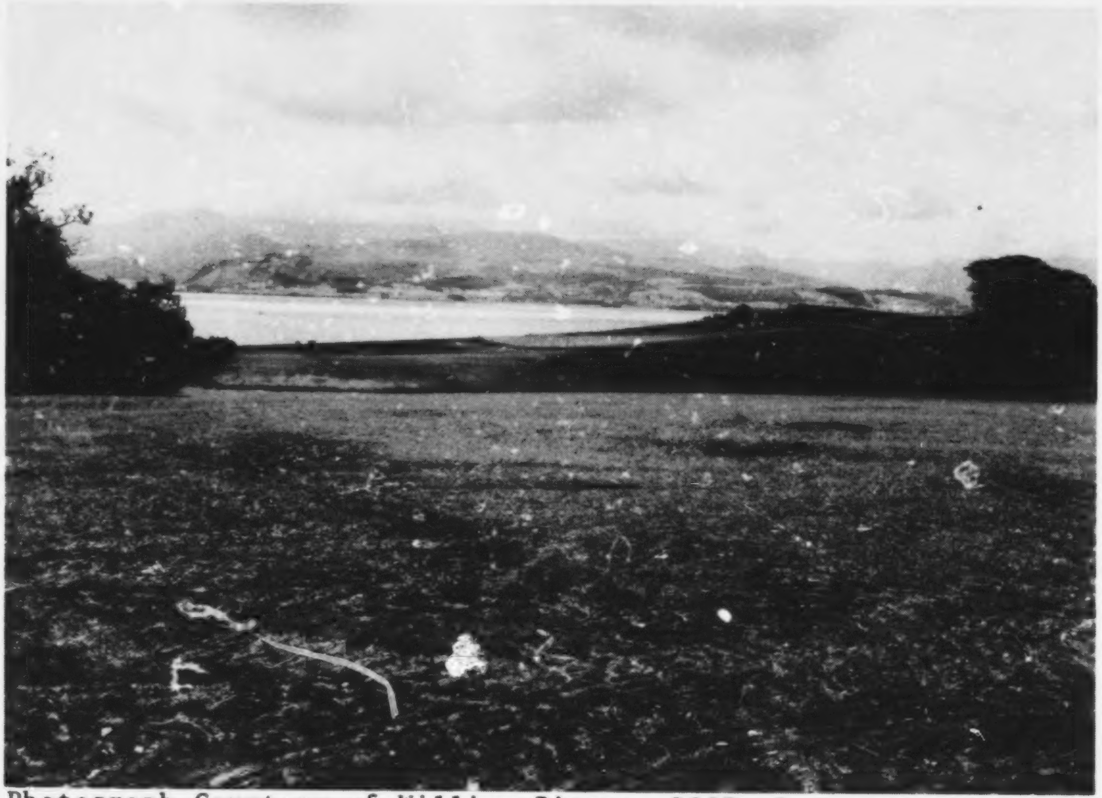
FIGURE 97. After the pipeline has been pulled completely across the Straits, it was ditched into the tidal flats using the equipment shown. The sand and mud was dug from alongside the pipeline allowing it to settle gradually into the ditch. Excavation was only possible at low tide. All excavated material was later replaced over the top of the pipeline, 1975.

barge back to the pipeline crossing where the spoils were dumped, covering the line.

Restoration

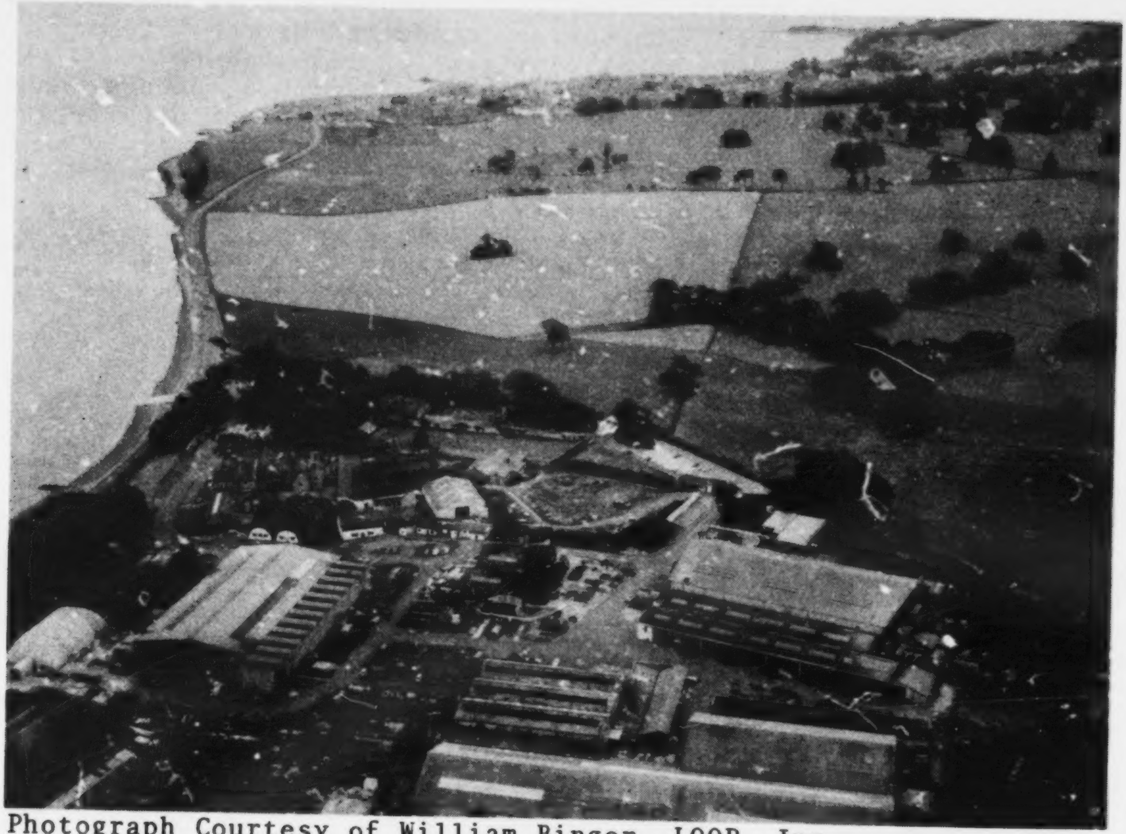
After the trenches had been refilled, both construction sites were graded to return the areas to their original contours, and the sites replanted with grass and shrubs. Since construction completion, a small stream draining on the Lavin Sands has been closely monitored to ensure that it does not cross the path of the pipeline. If this were to occur, the stream would have to be diverted to prevent washing out the trench and exposing the line. One month after work finished on the tidal flats, the area had returned to its original conditions. Figures 98 through 100 show conditions at the landfalls just after restoration was completed.

Surveys taken by a local university to monitor physical processes in the Straits prior to construction have continued at quarterly intervals. Bird surveys conducted by the Nature Conservancy before and after construction revealed no significant population changes. There was also a concern about the impact of dredging and dredge-induced pollution with regard to shellfish beds some two kilometers from the crossing. Dredging and trenching operations were regulated to avoid adverse effects on the shellfish.



Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 98. Ground View of Work Site Following Restoration, 1975.



Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 99. Aerial View of Work Site Following Cleanup and Reseeding. The route of the pipeline is through the center of the darker strip across the center of the photo. The black strip across the highway is the location of the pipeline crossing under the road, 1975.

Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 100. View of the Winch Site Following Cleanup and Restoration Before Replanting, 1975.

SECTION 5

LANDFALL CASE STUDIES: PLANNING APPROACHES TO MINIMIZING IMPACTS

To augment the technical methods available for minimizing potential environmental effects from pipeline installation, regulation of a particular landfall's installation and restoration can also be used to control the extent of environmental damage. This chapter presents two landfall case studies -- highlighting regulations developed to address technical and environmental constraints of particular landfall sites. The successful installations at both landfalls -- the LOOP crude oil pipeline in Southern Louisiana and Shell/Esso's gas pipeline at St. Fergus, Scotland -- illustrate that effective and acceptable regulations for pipeline installation and restoration can be developed through cooperative planning between government and industry.

The following aspects of regulatory activity are considered in each example:

- type and jurisdiction of government agencies involved;
- the stage in industry planning at which agencies became involved;
- types and sources of information required to formulate environmental protection plans/stipulations; and
- regulations placed on installation and restoration.

THE LOUISIANA OFFSHORE OIL PORT (LOOP)

In June 1979, the 48-inch diameter crude oil delivery pipeline for the Louisiana Offshore Oil Port (LOOP) Project was installed across a narrow sand beach in southeastern coastal Louisiana. The LOOP Project -- an offshore marine terminal, associated pipelines and storage facility -- has been designed to help supply Louisiana and Midwest refineries with crude oil. Two agencies have been involved in the majority of regulatory activity for this facility:

- The U.S. Coast Guard (DOT) -- which was designated by the Deepwater Port Act of 1974 as the lead federal agency for licensing U.S. deepwater port construction and operation; and

- The Louisiana Offshore Terminal Authority (LOTA) -- an agency within the State's Department of Transportation and Development which was set up to promote development of a deepwater port and to regulate development and subsequent operation such that Louisiana's coastal environmental values would be preserved.

Before discussing regulatory and licensing stipulations on this facility -- and, in particular, on the associated pipelines -- it is necessary to understand the development of the terminal proposal and the evolution of federal and state regulation of deppwater ports.

Development of Louisiana Deepwater Ports : Background

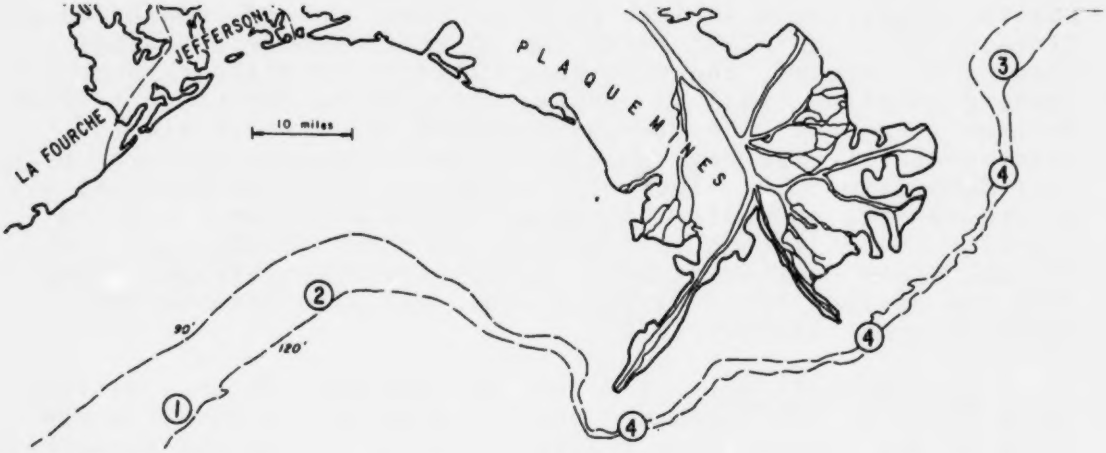
Development of deepwater port facilities off Louisiana's coast has been given serious consideration since the early 1970's. The first proposals, made in 1971, came from oil companies who wished to develop two offshore oil lease tracts in Garden Island Bay (part of the Mississippi River delta) as deepwater port sites. This proposal raised many legal and environmental issues, and as a result, the sites were not developed. However, the proposals did trigger a number of studies of Louisiana deepwater port development feasibility which were undertaken by both government and industry. The state was initially interested in any type of deepwater bulk cargo facility; industry focused solely on an offshore oil terminal to handle crude for Louisiana and Midwest refineries.

Early State Involvement -- The Deep Draft Harbor and Terminal Authority: In early 1972, Louisiana governor-elect Edwin Edwards organized a "Superport Task Force" to assess deepwater development feasibility based on economic, environmental and practical considerations. After an initial favorable assessment, the State Legislature passed legislation creating a new state agency specifically to deal with offshore ports -- the Deep Draft Harbor and Terminal Authority. The Authority was given the power to "promote, plan, finance, develop, construct, control, license, regulate, supervise, operate, manage, maintain and/or modify offshore terminal facilities" (State of Louisiana, 1972) including (as the Act defines) all associated offshore and onshore pipelines. Although authorized originally to consider direct state ownership of a deepwater port, the Authority -- whose name has since been changed to the Louisiana Offshore Terminal Authority (LOTA) -- chose to focus its activities on acting as the lead agency for licensing and regulating private development, including construction, inspection, and environmental monitoring.

Industry Involvement -- Forming LOOP, Inc.: In 1972, independently from the state, a group of oil companies undertook their own study which looked exclusively at the feasibility of developing a deepwater crude oil handling terminal to service Louisiana refineries. After preliminary analysis, a consortium of ten companies formed "Louisiana Offshore Oil Port, Inc." (LOOP) in October 1972. The consortium focused on development of a detailed design for a port to move oil from the offshore receiving terminal to an existing onshore terminal at St. James, Louisiana. Initially, four locations were considered: one to the east of the Mississippi River; one near the passes of the Mississippi River; one offshore near Grand Isle, LA; and one offshore of Lafourche Parish, LA. (The areas considered for potential terminal development are illustrated in Figure 101). Numerous factors, including mud slide areas and the longer routes from other sites, (approximately 115 miles vs. 78 miles) caused LOOP officials to concentrate further effort on the Lafourche area (Louisiana Offshore Oil Port Feasibility Study, 1972).

Issuance of LOOP licenses: In January 1975, the Federal Deepwater Port Act -- designed to authorize and regulate the location, ownership, construction and operation of deepwater ports, and to provide protection for the marine and coastal environment -- was signed into law. The Department of Transportation (DOT) was designated as lead federal agency and in November, 1975, final federal regulations for superports were issued. Within DOT, the Office of Deepwater Ports was assigned policy responsibility as well as overall supervision over the total licensing process. The Secretary of DOT delegated to the Coast Guard the responsibility for receiving and processing deepwater port license applications and for recommendations concerning issuance or denial of licenses.

In December, 1975, LOOP, Inc. applied to the Coast Guard and to the Louisiana Offshore Terminal Authority for licenses to construct and operate a deepwater single point mooring (SPM) crude oil offloading terminal, associated pipelines, booster station, storage terminal and other necessary facilities offshore and in coastal Louisiana. After preparation and issuance of an Environmental Impact Statement (EIS) by the Coast Guard, a federal license was granted in January 1977. Within 10 days, Louisiana Offshore Terminal Authority issued the state license. In August 1977, LOOP, Inc. accepted the federal and state licenses and the Project was legally underway.



	1	2	3	4
ADVANTAGES	1. Open for Fairway 2. Nearest to St. James 3. Fair Terminal Site	1. Slightly more Protected Water	1. Fair distance to Shore 2. Open for Fairway	1. Near Shore
DISADVANTAGES	1. Distance from Shore	1. Among Oil Operations 2. Distance from Shore	1. Distance to St. James & Oyster Leases 2. Less Protected Water 3. River and Major Pass Crossings 4. More Expensive Tankage 5. Bird Sanctuary & Public Shooting 6. Require Marine Operation 7. Commercial Fishing	1. Mud Slide Areas 2. Distance to St. James & Oyster Leases 3. River and/or Major Pass Crossings 4. More Expensive Tankage 5. Ship traffic and Oil Operations 6. Bird Sanctuary & Public Shooting 7. Less Protected Water

SITE SELECTION - MARINE FACILITIES
LOUISIANA OFFSHORE OIL PORT

Source: Louisiana Offshore Oil Port Feasibility Study, 1972.

FIGURE 101. Potential Terminal Development Areas.

Pipeline Installation

Project Facilities: Figure 102 illustrates the locations of major facilities associated with the LOOP project. The project is designed to be constructed in three phases with a total capacity to carry 3.4 million barrels per day. The first phase of the project consists of three complete single point moorings (SPM) and one pipeline feeding into the storage terminal with a carrying capacity of 1.4 million barrels per day. Each SPM is designed to moor vessels up to 700,000 dead weight tons (DWT) in seas up to 15 feet significant wave height. The SPM will be attached to a pumping platform via a 56-inch diameter, 8000-foot long buried pipeline. The major coastal pipeline, a 48-inch diameter line, extends approximately 21 miles from the platform to the shoreline where a booster station is located, and then an additional 23 miles through a dredged pipeline canal in coastal wetlands to the Clovelly Dome Storage Terminal. The storage terminal consists of eight underground storage caverns created by freshwater leaching of a salt dome structure. The brine resulting from the leaching will be transported offshore through a 30-inch pipeline. A third pipeline, 4 1/2 inches in diameter, to carry diesel fuel from the shoreline booster station to the offshore platform, along with the 30-inch brine disposal line, are also laid in the pipeline canal (Binger 1979).

The Landfall Setting: The LOOP landfall is on a narrow, sandy beach on the Louisiana coast approximately 55 miles due south of New Orleans (see Figure 102). It is located about five miles east of Bayou Lafourche, a slow-moving river used extensively by shrimpers for mooring and boat repair. The beach, about 50 feet wide, is backed by wetland. The first river intersecting the pipeline canal -- Bayou Moreau -- is about 1250 feet from the waterline. The landfall area is illustrated in Figure 103. Between the sandy beach and the Clovelly Dome Storage area -- 23 miles inland -- the pipeline canal passes through salt, brackish and freshwater marshes, crossing numerous pipelines and canals dredged for petroleum development activity. Figure 104 illustrates the wetland system. Vegetation along the banks of the canal (running left to right in the picture) illustrates typical emergent growth which appears on spoil banks created on either side of a dredged canal.

Landfall Installation: Installation of the landfall and wetland pipelines began in January 1979 with the dredging of a pipeline canal approximately 50 feet wide and 3 to 15 feet deep from the Fourchon Booster Station to the shoreline. Pipeline canal width and depth varied inland depending on many factors. Dredging was done with land excavators or marsh buggies in areas with sufficient bearing strength; where conditions were not

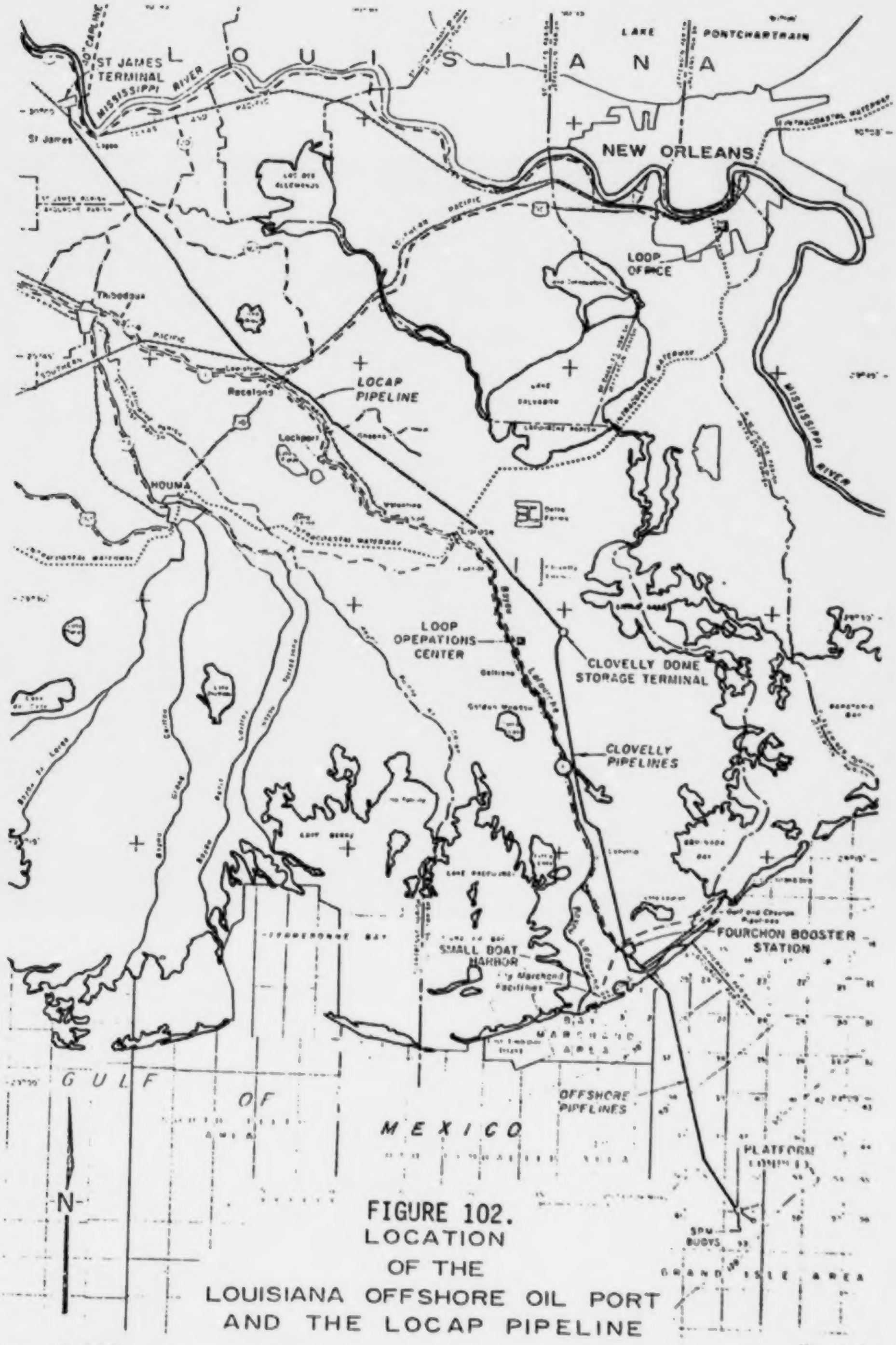
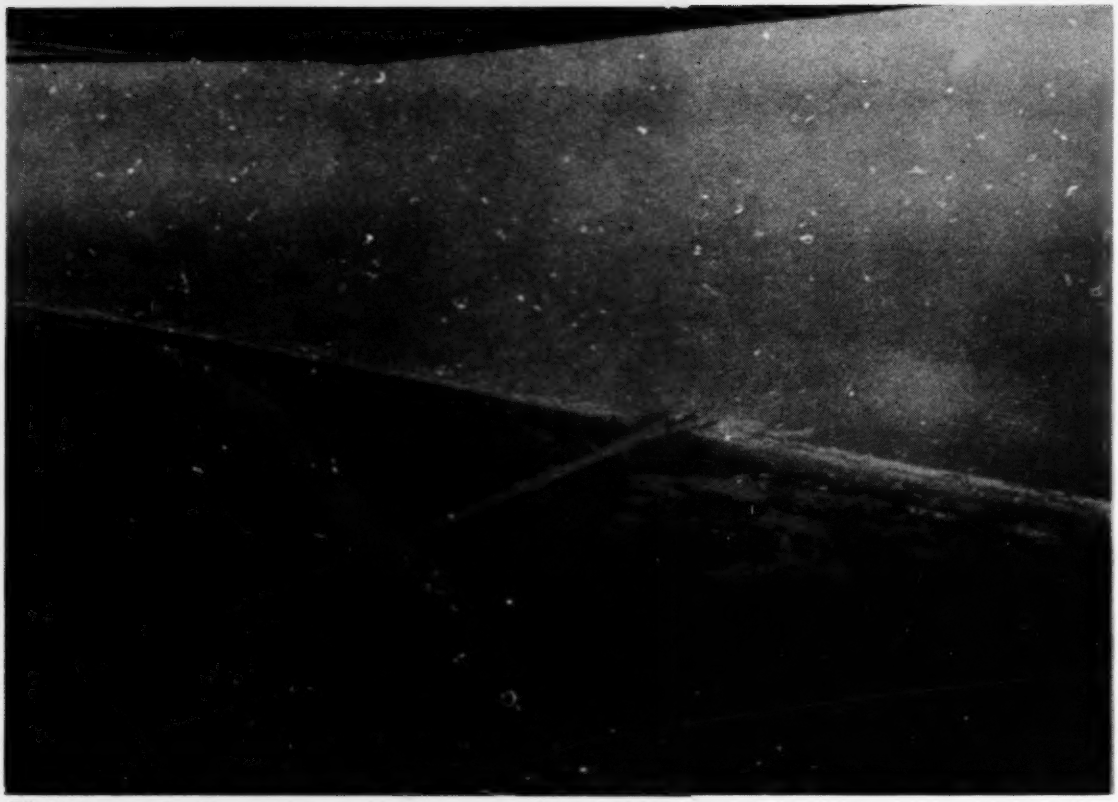

LOUISIANA
LAKE PONTCHARTRAIN
ST JAMES TERMINAL
MISSISSIPPI RIVER
St James
NEW ORLEANS
LOOP OFFICE
Thibodaux
Raceland
LOCAP PIPELINE
Lockport
HOUMA
LOOP OPERATIONS CENTER
CLOVELLY DOME STORAGE TERMINAL
CLOVELLY PIPELINES
MISSISSIPPI RIVER
FOURCHON BOOSTER STATION
SMALL BOAT HARBOR
TERREBONNE BAY
OFFSHORE PIPELINES
PLATFORM
SPM BUOYS
GRAND ISLE AREA
GULF OF MEXICO
N

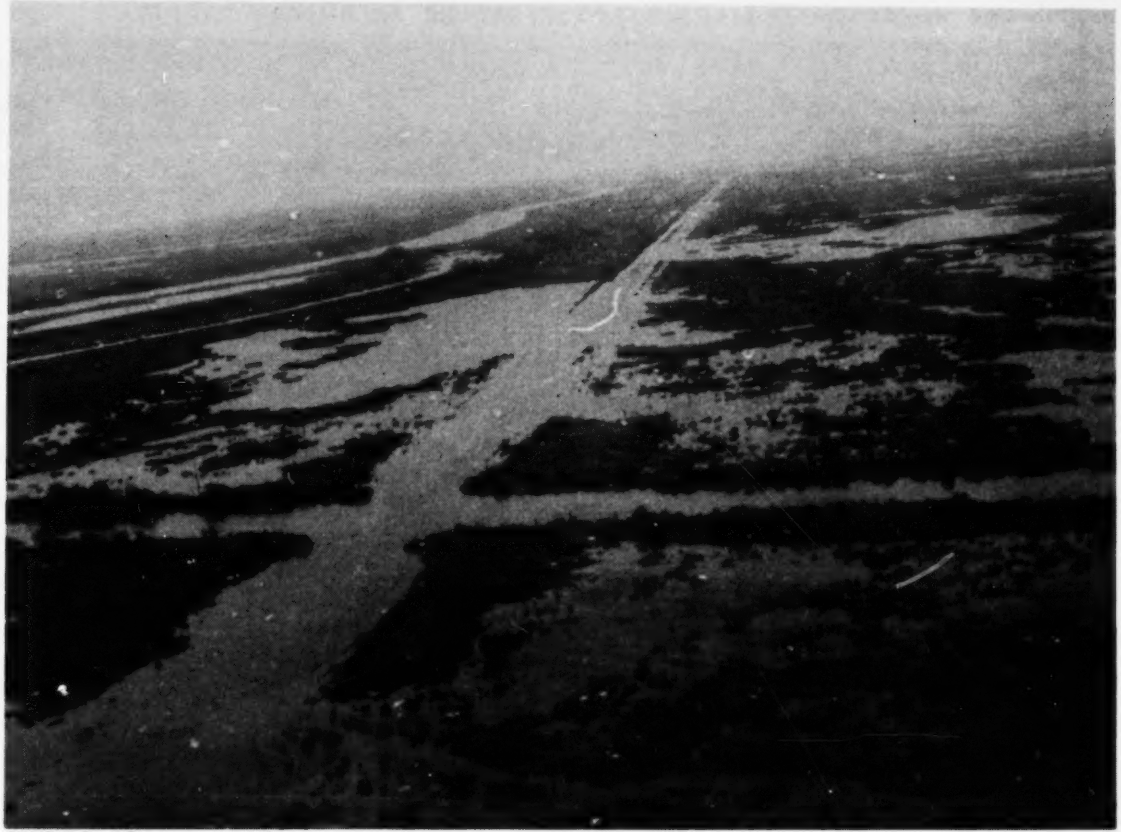
FIGURE 102.
LOCATION
OF THE
LOUISIANA OFFSHORE OIL PORT
AND THE LOCAP PIPELINE

Source: LOOP, Inc., 1979.



Photograph Courtesy of James Webb, LOTA.

FIGURE 103. LOOP Landfall Construction, June, 1979.



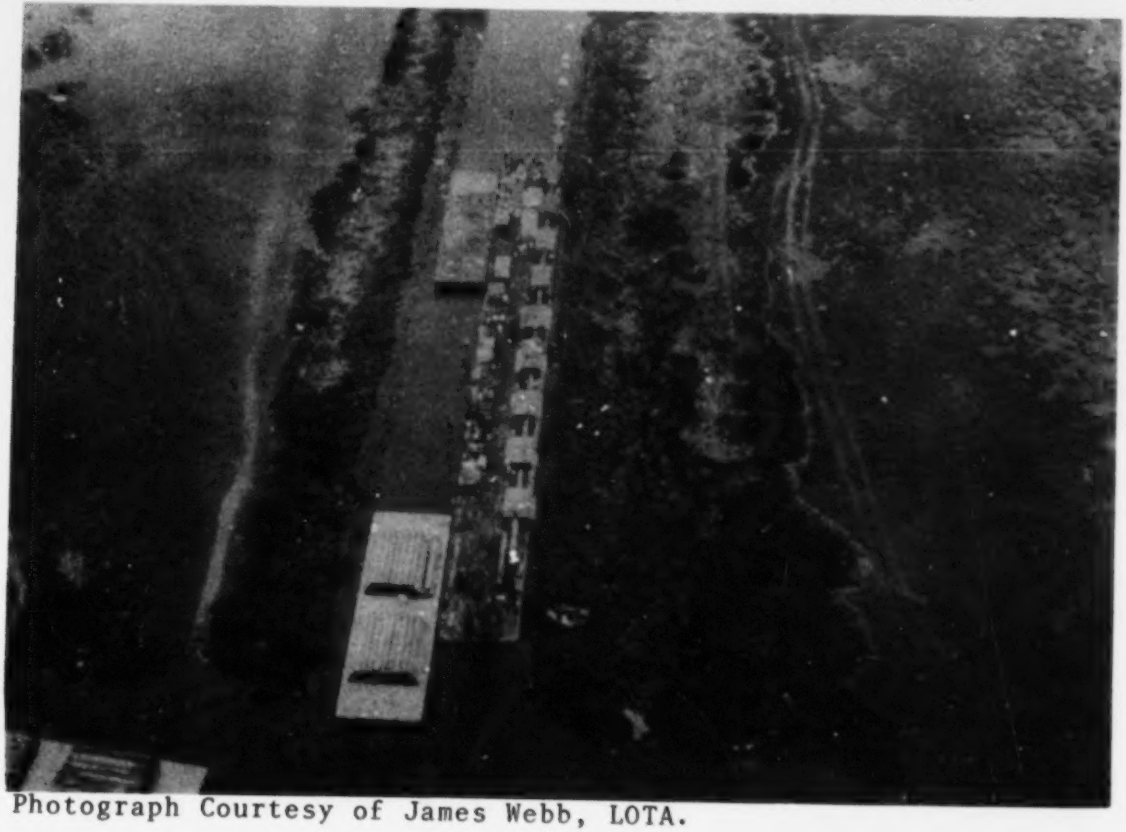
NERBC Photograph.

FIGURE 104. Coastal Louisiana Wetlands.

favorable, barge-mounted dredges were used. Where marsh buggies were utilized, canals had minimum dimensions of twelve feet wide by eight feet deep. In other areas canals were excavated up to seventy feet wide by twenty-two feet deep.

The 48-inch diameter pipeline running from the storage area to the Fourchon Booster Station, two and one-half miles inland of the landfall, has a wall thickness of 0.438 inches, except at canal and road crossings, where the thickness is increased to 0.500 inches. It is coated with a corrosion barrier of asphalt and sand, and a weight coating of wire-reinforced concrete. From the Booster Station to the offshore pumping platform, the pipeline has a 0.625 inch wall thickness, and is coated with a semiplasticized coal-tar enamel with fiberglass reinforcement for corrosion protection and a concrete weight coating (Binger, 1979).

As illustrated in Figure 105, the pipe lengths were welded and the welds coated on barges floating in access canals.

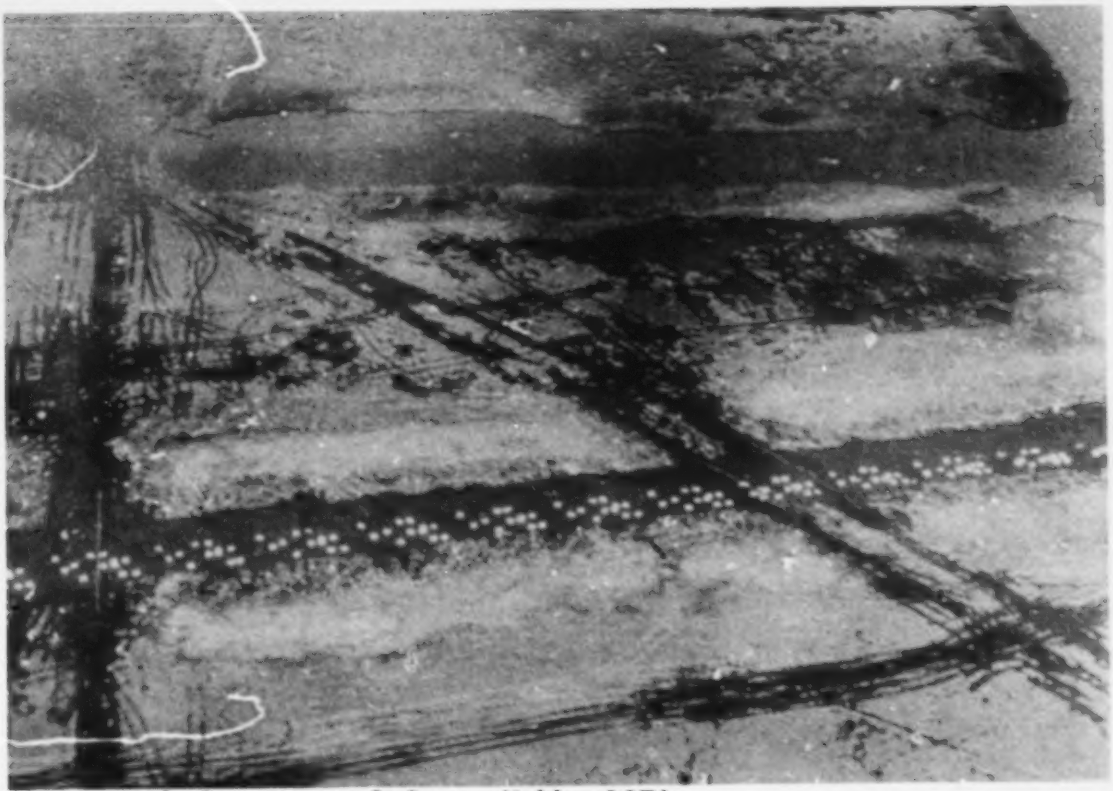


Photograph Courtesy of James Webb, LOTA.

FIGURE 105. Pipeline Welding.

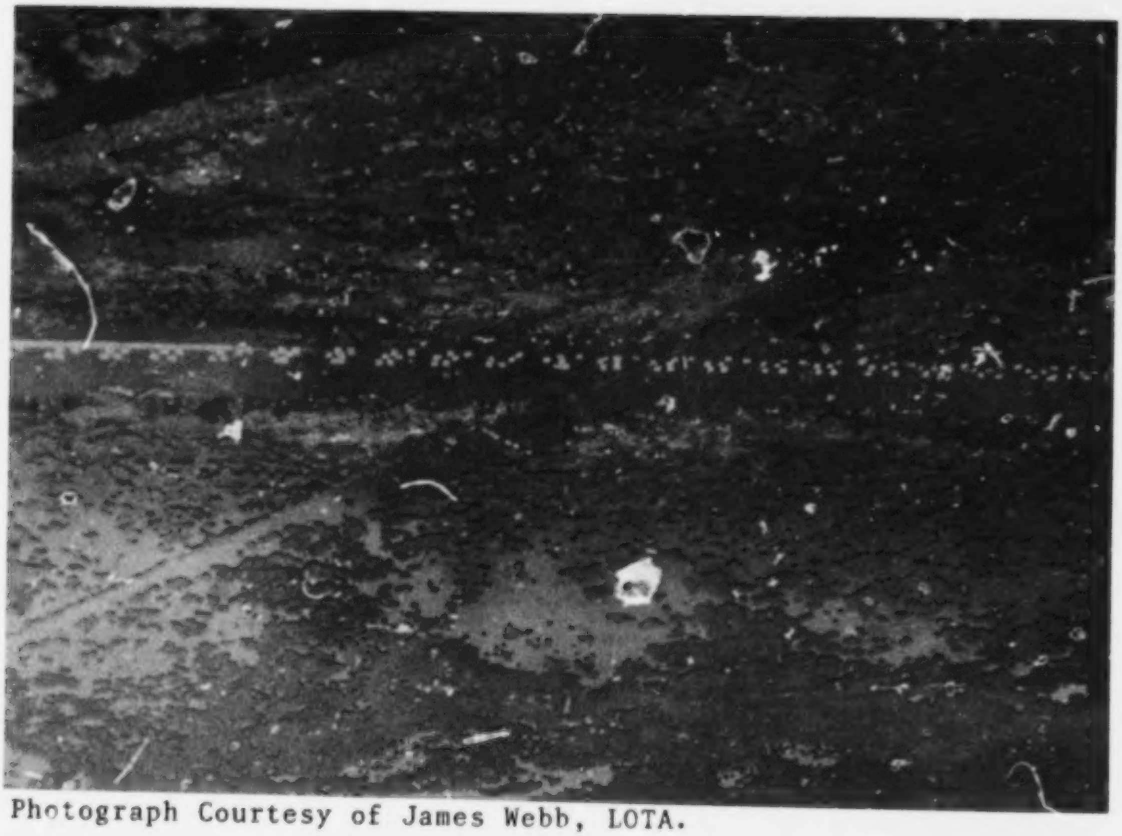
Styrofoam floats were attached to the line to provide bouyancy to the pipeline until burial, and the line was then laid off a pipeline barge which moved down the canal from the storage terminal to the shoreline. Lines which have been laid and are floating in the canal are illustrated in Figures 106 and 107. The new lines crossed 34 existing pipelines -- 10 major large diameter pipes and 24 smaller diameter flow lines. Where crossed, the old lines were raised up to the surface, the new lines laid beneath, a 2-foot deep sand bag and shell pad placed over the new lines, and the old lines relaid (see Figure 106).

In early June 1979, a pipeline trench approximately 15 feet deep and 40 feet wide was cut across the beach and into the surf zone. A vessel equipped with pulling winches was then stationed offshore and connected to the pipeline with a cable. The pipeline was pulled across the beach landfall and



Photograph Courtesy of James Webb, LOTA.

FIGURES 106. Pipelines Floating in Canal.



Photograph Courtesy of James Webb, LOTA.

FIGURE 107. Pipelines Floating in Canal.

approximately one and one-half miles offshore. Figures 108 and 109 show the pull underway. The floats attached to the pipe (seen in Figure 103 which also illustrates the pull) maintained the line just touching the bottom and thus minimized friction from the pull. The pull of all three lines (48", 30" and 4 1/2") required just under four days. The beach trench was then immediately refilled. The total time the landfall was under construction was approximately one month.*

Pipeline Right-of-Way Restoration Techniques and Regulations

From the project's inception, both the developer and the various governmental regulators recognized that special attention to restoration would be required to minimize damage to the landfall and wetland ecosystem. As project planning progressed, both groups worked together and with other interested

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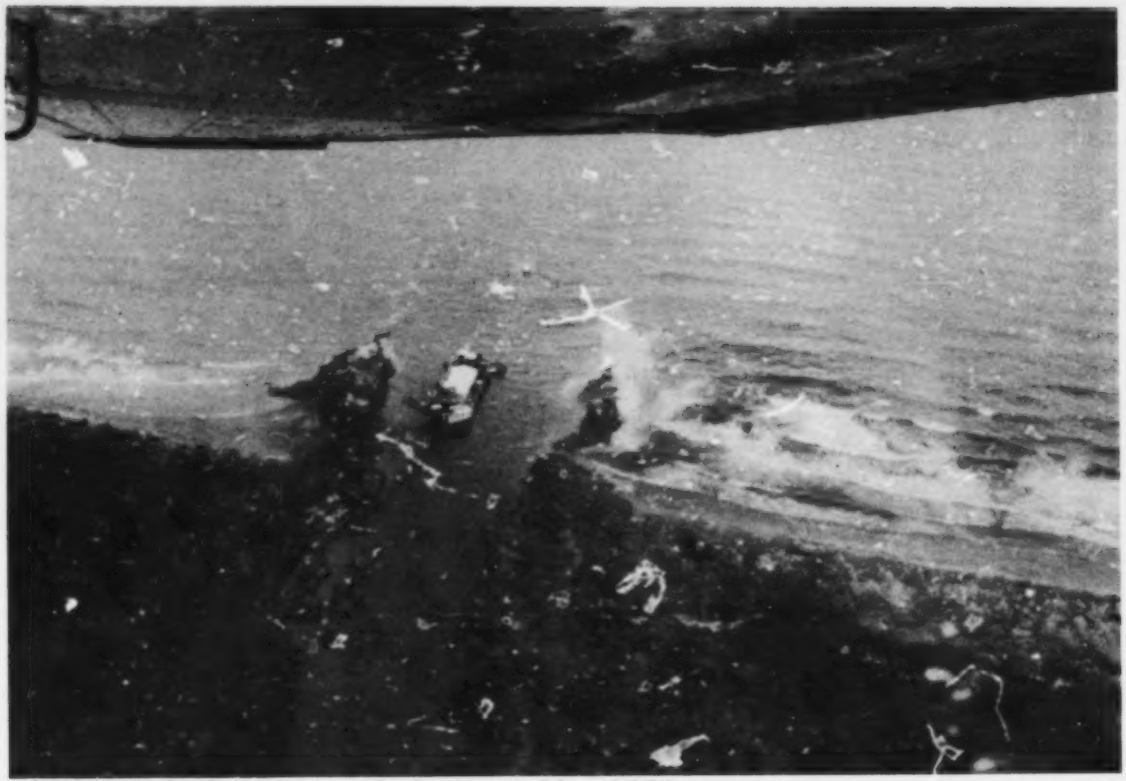
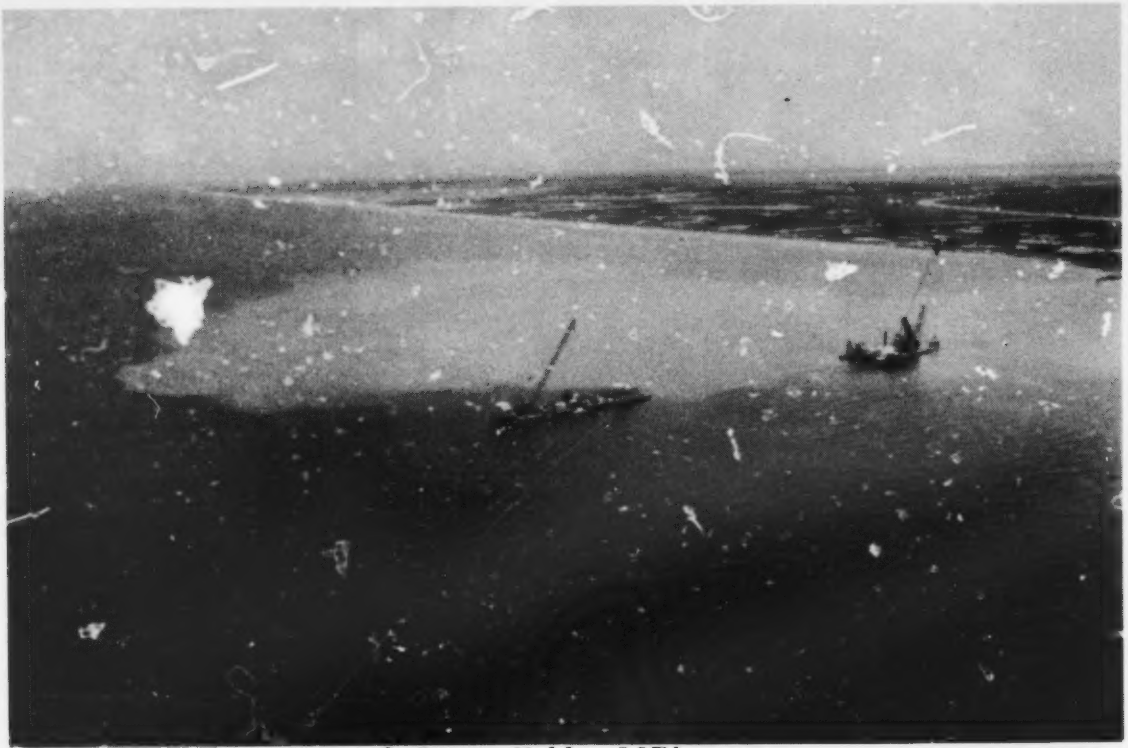
* W.P. Binger, (Louisiana Offshore Oil Port, Inc., Harvey, LA) 1979: personal communication.



Photograph Courtesy of James Webb, LOTA.

FIGURE 108. The Pipeline Pull, June 1979.



Photograph Courtesy of James Webb, LOTA.

FIGURE 109. The Pipeline Pull, June, 1979.

parties to address the issue of the most appropriate methods for right-of-way restoration.

The LOTA Environmental Protection Plan: Recognizing the value of Louisiana's coastal wetlands, the legislation creating the Offshore Terminal Authority also required the development of an Environmental Protection Plan to assess the potential impacts from terminal construction and operation and to outline requirements for development based on minimizing these effects.

To help develop the Environmental Protection Plan, the Authority contracted with Louisiana State University (LSU) Center for Wetlands Resources to assess existing environmental conditions and to make recommendations on the Environmental Plan's contents. For these "Superport Studies" (which took place prior to the LOOP proposal), LSU focused on the coastal area west of the Mississippi delta to Timbalier Bay as the most likely location for a deepwater port (see Figure 101 for location). Their final four volume report, Louisiana Superport Studies, was completed in October 1973.

The original Environmental Protection Plan -- detailing how offshore terminal development would be designed to protect the environment -- was adopted on January 15, 1974. The plan, based in large part on the recommendations contained in the Superport Studies, was developed by a three-member committee: LOTA's Executive Director, the Director of the Louisiana Wildlife and Fisheries Commission, and the Director of LSU's Center for Wetlands Resources.

As stipulated by the Louisiana Deepwater Port Act, the major points to be considered in the plan were:

- stresses on the natural and human environment;
- existing data available to assess potential environmental damage;
- comparisons of environmental and economic considerations and development of a best "economic/ecologic formula" for choosing optimum port sites; and
- methods which could be used to minimize potential emvironmental damage.

Mentioned in the plan as potential stresses associated with pipeline siting are: creation of new tidal passes as a result of crossing barrier islands; interference with sand transport necessary for barrier island maintenance; obstruction of littoral drift if pipelines were unburied; and alteration of estuarine water circulation and salinity balance if existing tidal passes were disrupted. In addition, the risk of spills and associated damage to coastal wetlands was considered a major potential stress.

To minimize these effects, the plan details:

- pipeline design criteria -- including leak detection and rapid shutdown devices, and pipeline burial at the landfall to a depth sufficient to protect against interferences with littoral drift; and
- construction guidelines for dredging operations, and for prevention of disruption of circulation and drainage patterns both offshore and in coastal wetlands.

The most direct means of minimizing pipeline impact, however, are the requirements for Authority approval of pipeline locations and for an ongoing biological program to monitor changes in the environmental system due to pipeline placement. The following "essential environmental considerations" regarding offshore pipeline siting were detailed in the plan:

c - Sea Bottom Characteristics.

Because poor foundation conditions, relatively steep seabed slopes, and mudlump areas could endanger offshore installations, including the possible rupture of the offshore pipelines connected to a deepwater port; a deepwater port and its offshore pipelines shall be located in areas which have stable sea bottom characteristics.

e - Offshore Pipelines.

Since the possibility of accidents is lessened if the offshore pipeline routing avoids contact with existing submarine installations, to the fullest extent possible, the offshore pipeline routing shall avoid crossings or other contacts with existing submarine installations.

f - Barrier Islands.

(1) Because barrier islands serve as a regulator for salt- and fresh-water balance in estuaries, serve as a sand source for beach fronts, help abate storm surges, and provide a physical setting for recreational activities, several stresses are created when a pipeline transects a barrier island, or when any significant construction is done on a barrier island. If a pipeline canal on a barrier island is not properly filled, a new tidal pass can be created.

(2) Because any significant construction activities on a barrier island could not be undertaken without provision for extensive erosion control techniques, which would impose additional ecological and physical stresses upon the barrier island, and because the location of a deepwater port or onshore facilities on a barrier island would be incompatible with the recreational uses and natural functions of such islands, the offshore pipeline routing shall not traverse any barrier island, and the onshore facilities shall not be located on a barrier island.

g - Tidal Passes.

Because the tidal passes are critical along the Louisiana coast because they control the water regime for the coastal wetlands, and they provide a route by which migratory estuarine species can enter and leave, to the fullest extent possible, the offshore pipeline routing shall not traverse a tidal pass. If a tidal pass must be traversed, it shall be neither permanently widened nor deepened, and shall be restored to its original condition immediately upon completion of pipeline installation (LOTA, 1977).

The following general requirements were placed on pipelines passing through coastal wetlands:

b - Because poor foundation conditions could cause facilities to buckle, rupture, or subside, onshore facilities shall be located in an area in which a stable foundation exists or can be developed, and in which adequate containment and flood protection can be provided.

c - Wetlands.

Because draining and filling wetlands destroys benthic populations and bottom spawning organisms, and removes the area from biological productivity, and because pipeline construction through coastal wetlands could cause changes in estuarine water circulation patterns, possible alteration of the fresh and salt water balance in the estuaries, and possible increases in the rates of erosion and subsidence, onshore facilities shall be located in an area in which a minimum alteration of wetlands is necessary for construction, and the routing of onshore pipelines through coastal wetlands shall be kept to a minimum (LOTA, 1977).

The plan also outlined essential considerations of the monitoring program which would include monitoring of:

(1) The environmental stresses caused by oil spills and other polluting instances;

(2) The air and water pollution levels in the Louisiana coastal environment;

(3) The offshore water column and offshore benthos;

(4) Shoreline, estuarine marsh, and freshwater swamp vegetation and fauna;

(5) The number, movement, and spawning and breeding cycles of wildlife in the Louisiana coastal environment;

(6) Saltwater intrusion;

(7) Water circulation and drainage; and

(8) Shoreline erosion and erosion along pipeline canals (LOTA, 1977).

LOOP, Inc. Consultations During Project Development: From the project's inception, LOOP officials consulted with various federal, state and local officials concerned with deepwater port development. As of the 1976 Draft Environmental Impact Statement (DEIS), the following agencies had been contacted by LOOP representatives:

Federal Agencies

Department of the Interior
Bureau of Land Management
United States Geological Survey
Bureau of Sports Fisheries and Wildlife (Fish & Wildlife Service)
Environmental Protection Agency
Army Corps of Engineers
Council on Environmental Quality
United States Coast Guard

Louisiana State Agencies

Offshore Terminal Authority, Dept. of Transportation and
    Development
Department of Wildlife and Fisheries
Stream Control Commission
Air Control Commission
Office of State Planning
Governor's Council on Environmental Quality
State Parks and Recreation Commission
Department of Art, Historical and Cultural Preservation

Local Agencies

Lafourche "Superport" Task Force
Greater Lafourche Port Commission
Lafourche Planning Commission
Municipality of Golden Meadow
Board of Commissioners of the Port of New Orleans

In addition, LOOP set up and maintained a Public Information Office and made numerous presentations to civic groups and professional organizations throughout Louisiana. These included groups such as the Sierra Club, Audubon Society, Louisiana Wildlife Federation, Louisiana Coastal Commission and the Ecology Center (DOT, 1976).

Pre-installation Surveys: After the Louisiana Superport Studies were finished by LSU's Center for Wetlands Resources in 1973, the Center continued its participation in environmental assessment of the proposed facility by preparing an Environmental Baseline Study for LOOP, Inc. The survey offered a detailed assessment of the existing environment in the development area, particularly in a primary impact area made up of three parishes -- Lafourche, St. James and Terrebonne. The report described these coastal features relevant to assessment of potential pipeline impacts:

- shoreline geology -- The landfall area is rapidly subsiding and is unique for Louisiana in that it is not bordered by barrier islands or offshore submarine sand bars. Another unique feature -- cheniers -- are found throughout the Bayou Lafourche delta. In troughs between pairs of these parallel sand ridges are bodies of water supporting biologically diverse communities.

- meteorology -- The shoreline area is a hurricane-, tropical storm-, cyclone- and tornado-prone area.

- vegetation -- Although the landfall does not contain dune or other fragile beach communities, coastal zone vegetation includes extensive, highly productive salt marshes (dominated by Spartina alterniflora) and unusually diverse vegetation in ponds and on ridges of the chenier habitat.

- fauna -- Protected or endangered species living in the LOOP project area include the American alligator, the brown pelican and the red wolf.

- use -- The shoreline and coastal area supports extensive oil and gas development activity and is criss-crossed by pipelines. Hunting and trapping also occur extensively in the LOOP project area (DOT, 1976).

Some types of environmental data for the LOOP project area had also been gathered by the Oyster Division of the Louisiana Department of Wildlife and Fisheries. Information on water chemistry, nekton, zooplankton, hydrology, sediments and benthic organisms have been sampled at 7 - 15 stations in an area to the west of the project on a weekly basis since 1967. Similar types of data have been collected to the east of the project's pipeline corridor since the late 1950's (LOTA, 1977b).

The Environmental Impact Statement: In April 1976, the Coast Guard issued its draft Environmental Impact Statement (DEIS) on the proposed LOOP facility. The DEIS assesses potential landfall effects as follows:

> The proposed Clovelly pipeline system would initially cross a narrow strip of beach. Due to rapid erosion, there are practically no large dunes associated with this beach community. The flotation canal method of construction would be employed in the beach area. There is only limited vascular vegetation associated with the beach due to its unstable nature. The primary inhabitants of the area are shorebirds which feed on the small animals found

on the beach and nest in the area. Impact to the avian inhabitants of this community would be limited to the construction period, when they will be forced to feed and/or nest outside of the area of activity. The beach is expected to return to a condition similar to its present state (DOT, 1976).

Effects of pipeline installation were expected to be greater in the salt marsh areas. The following effects were anticipated:

- suspension and redistribution of sediments and interstitial waters -- This was thought to have potentially significant adverse effects near the storage terminal where sediments are contaminated with hydrocarbons from petroleum development activity;

- disruption and/or elimination of tidal wetland habitat -- Loss of approximately 1450 acres of wetland within the construction right-of-way, which represents about 0.3% of the Barataria basin drainage, was projected as a worst case; and

- interference with tidal sheet flow movement -- Creation of spoil bank levees on either side of the pipeline canal were projected to cause potential interference with tidal sheet flow water movement across the marsh. This problem was anticipated to potentially affect approximately 16,000 acres of wetland, and to be of particular significance to the wetland between Bayou Lafourche and the canal (DOT, 1976, p. 3.45-7).

The DEIS seemed to indicate, however, that the creation of additional canal-type surface drainage might cause the greatest potential damage. Based on information provided by Dr. Lyle St. Amant, Director of the Lousiana Wildlife and Fisheries Commission, the following assessment was presented in the DEIS:

> The LOOP pipeline construction activity would result in significant additional canal-type drainage across the north/south estuarine salinity gradient. The LOOP pipeline canal would be the widest lengthy north/south channel in the Barataria drainage east of Bayou Lafourche. It would serve, as have other smaller canals, as a vehicle for directing tidal flows that would otherwise disperse over a much wider area of wetland. Observations of existing canals suggest this would result in greater localized salinity fluctuations over given tidal cycles than would otherwise occur. While the long-term

mean salinity of any given area along the canal might remain similar to that in undisturbed wetland, the biota of the canal drainage would be regularly exposed to extremes not characteristic of the undisturbed area.

The impact of these changes in salinity could be significant to biota whose habitat selection is salinity-limited, such as the two dominant commercial species of Penaeid shrimp. The postlarval through subadult stages of the brown and white shrimp have distinct salinity preferences in the estuary. Increasing salinity fluctuations could be detrimental to the maturation of either or both species. The relatively high salinity marshes of the lower Barataria drainage are the major brown shrimp nursery grounds in coastal Louisiana (DOT, 1976).

The LOOP Environmental Monitoring Program: In January 1977, licenses for the LOOP facility were issued by both Coast Guard and the Louisiana Offshore Terminal Authority. Both licensing agencies required preparation of an Environmental Monitoring Program. This Program was developed by the three environmental directors (of LOTA, the LSU Center for Wetlands Resources and the Department of Wildlife and Fisheries) who had drafted LOTA's Environmental Protection Plan. The Monitoring Program was finalized in June 1977, and accepted by LOOP management on August 31, 1977. It was then transmitted to the Coast Guard.

The Program outlines a specific monitoring program which was to begin about one year prior to construction and continue through construction and operation of the facility. The Program, which began in 1977, is conducted by the Louisiana Department of Wildlife and Fisheries with funding from LOOP, Inc. and focuses on periodic sampling at predetermined stations. Parameters measured include: hydrocarbons, heavy metals, sediments, nekton, zooplankton, chlorophyll a, pH, water chemistry and water and air temperatures.

In addition, the Program outlined special field surveys and aerial photography to be performed along the pipeline right-of-way:

4. Monitoring of bird populations, including waterfowl, will occur during aerial examination of the pipeline right-of-way. This type of monitoring will begin approximately one year before construction and continue throughout construction and operation. Counts of muskrat houses and other indications of fur animal

populations will be made during these flyovers.

5. Aerial examination of turbidity plumes, erosion, levee breaks, pipeline breaks and oil spills along the pipeline route will be made monthly during the construction. During operation, surveillance by air along the pipeline route will also be made.

6. Low altitude photographs of the pipeline corridor will be taken semiannually prior to construction and annually thereafter.

8. A benthos study along the pipeline route will be performed to determine the effects of dredging on population distribution, density, and recovery time. Analyses of water chemistry, sediments (including petroleum hydrocarbons), and plankton populations will be performed at each benthos station. Where feasible, station locations will coincide with those used by LSU and NSU (Nichols State University) during their 1973-74 surveys. Station sites for this survey will be confined to the pipeline corridor but will also include the area of brine discharge and the offshore platform complex. One survey will be made just prior to dredging and another immediately after dredging. Benthic surveys will be made during the fall and spring prior to construction and again seasonally after construction. Benthic surveys along the pipeline will be discontinued after conditions stabilize.

9. A vegetation study will be conducted at monitoring stations to be designated in each of the major environments (saltmarsh, brackish marsh, intermediate marsh, fresh marsh, swamp forest) transected by the pipeline. Vegetation descriptions along the pipeline right-of-way will include percent ground cover, percent of dominance, diversity and species identification. Salinity will be monitored quarterly before, during and after construction. Ground level examination will be augmented with aerial photography. After the area recovers or stabilizes, quarterly monitoring will be discontinued.

10. To correlate changes in ambient conditions with LOOP's project, information will be provided by LOOP on the magnitude, time and location of all significant pollutant discharges (LOTA, 1977b).

In November 1977, vegetation and animal surveys began along the pipeline routes. The first year's surveys, undertaken by LSU for the Department of Wildlife and Fisheries, focused on inventorying existing species type, number and distribution along the pipeline corridor. This assessment of conditions as they existed immediately before installation will provide baseline information against which changes (if any) from construction can be measured.

Restoring the Landfall: Immediately after the pull, the pipeline trench was refilled with excavated material and original topography was restored. Although originally beach materials were to be excavated in two distinct layers -- the upper few centimeters separately from remaining sand -- quantities of upper layer materials were insufficient to allow successful separation. Because the beach materials were relatively homogeneous, however, natural resorting occurred quickly, and the beach appeared restored within three months.*

The pipeline was buried to a depth of ten feet over the top of the line as far back as the sand beach extends -- approximately fifty feet. The dredging of a small boat harbor in Bayou Lafourche to service the offshore platform will provide additional material to fill through the salt marsh back approximately 1000 feet to Bayou Moreau.* This amount of total fill restoration was based on projected erosion rates of 12-15 feet per year and was stipulated by the Louisiana Department of Public Works, which provides engineering advisory services to the state.**

Figure 110 shows the landfall after a hurricane in August 1979, less than two months after the beach portion of the trench was refilled. Restoration was sufficient at that point to prevent washout of the beach area. Figure 111 shows the landfall in September 1979. The pipeline canal to the west of the LOOP line (at the top of the Figure 111 photo) was installed in 1957. Its landfall is virtually indistinguishable from the remainder of the beach. Figure 103 (on page 123) illustrates where the canal crosses Bayou Moreau -- the distance back from the landfall for which complete backfill is planned; it is assumed that spreading of surrounding plants will cause natural revegetation of the disturbed area.

Restoring the Saltmarsh: At LOTA's request, extensive refilling of the trench, providing three feet of cover over the pipeline, is planned. Dredged materials will be replaced by clamshell dredger in the trench, with "plugs" (dikelike mounds built up higher than ground level) placed every 500 feet along the canal. At every major waterway, shell bulkheads will be built; dredged materials will be used for other plugs. Rather than a straight canal, therefore, the affected area will be restored to a series of shallow water pockets, each two to three feet deep, separated by earthen dikes every 500 feet. No planting will be undertaken; natural overgrowth will be relied upon to revegetate the canal.* A restoration time of approximately five years is estimated.**

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* J.C. Webb, (Louisiana Offshore Terminal Authority, Baton Rouge, LA), 1979: personal communication.

** W.P. Binger, (Louisiana Offshore Oil Port, Inc., Harvey, LA), 1979: personal communication.

Refilling of the trench in this manner was required by LOTA to address a number of potential pipeline canal-related effects which were projected in the EIS. These include:

- loss of tidal wetland habitat -- Assuming successful natural revegetation, it is projected that much of the originally disturbed area along the right-of-way will return to its original condition;
- interference with tidal sheet flow -- The removal of spoil bank levees by returning dredged materials to the canal, and placement of shell bulkheads at every major waterway, are expected to minimize long-term interferences with sheet flow water movement; and
- creation of canal-type surface drainage -- By placing plugs at 500-foot intervals along the canal, north-south drainage is prohibited. Long-term effectiveness of this method is, however, uncertain. As stated in the DEIS, "bulkheads have a history of rapid deterioration in the Louisiana coastal zone, sometimes hastened by the actions of local boatmen seeking navigational shortcuts." (DOT, 1976).

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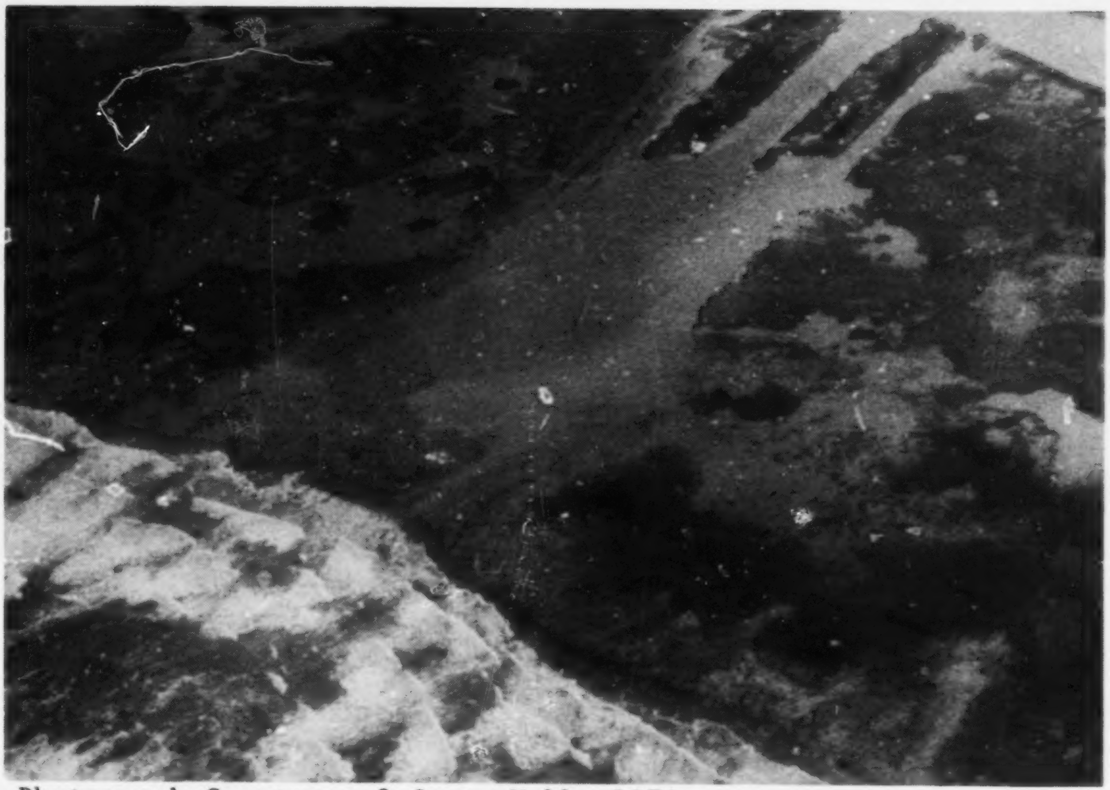
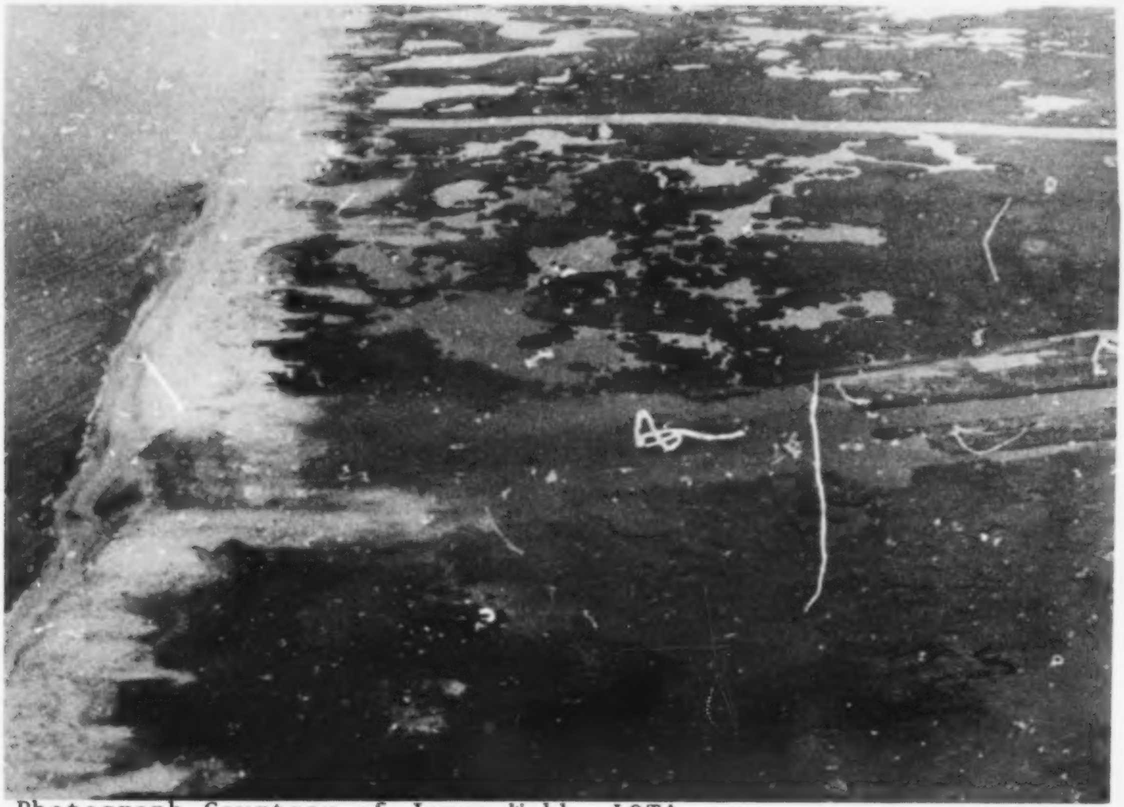
* Some researchers indicate that the plant species found in the Louisiana coastal marshes will not grow in open water conditions. Rather than closing up, therefore, it is anticipated that these open water pockets may expand. This is illustrated by petroleum-related canals dredged in the 1950's which have opened from initial widths of 30 feet to 120 feet by 1979. (S. Gagliano, 1979: personal communication.) (However, frequently these canals have been used for navigation with associated erosion due to vessel wakes. It is hoped that periodic bulkheading of the LOOP canal will prohibit its use for vessel traffic.)

** A.J. Heikamp, (Louisiana Offshore Oil Port, Inc., Harvey, LA), 1980: personal communication.



Photograph Courtesy of James Webb, LOTA.

FIGURE 110. The Landfall, August 1979.



Photograph Courtesy of James Webb, LOTA.

FIGURE 111. The Landfall, August 1979.

Restoration Success: As illustrated in Figures 110 and 111, restoration of the beach portion of the landfall has been successful. Although much of the marsh restoration has not been completed, Figure 112 illustrates a section of refilled canal; here it appears that preconstruction conditions may be restored. The monitoring program will provide a continuing assessment of restoration success. Cost to refill was estimated at approximately $1 million.*

THE FAR NORTH LIQUIDS AND ASSOCIATED GAS (FLAGS) PIPELINE

On July 14, 1976, a 36-inch diameter pipeline was pulled ashore on a sandy beach at the British Gas St. Fergus terminal on the northeast Scottish coast. The pipeline, carrying natural gas and associated liquids, connects the terminal with Shell/

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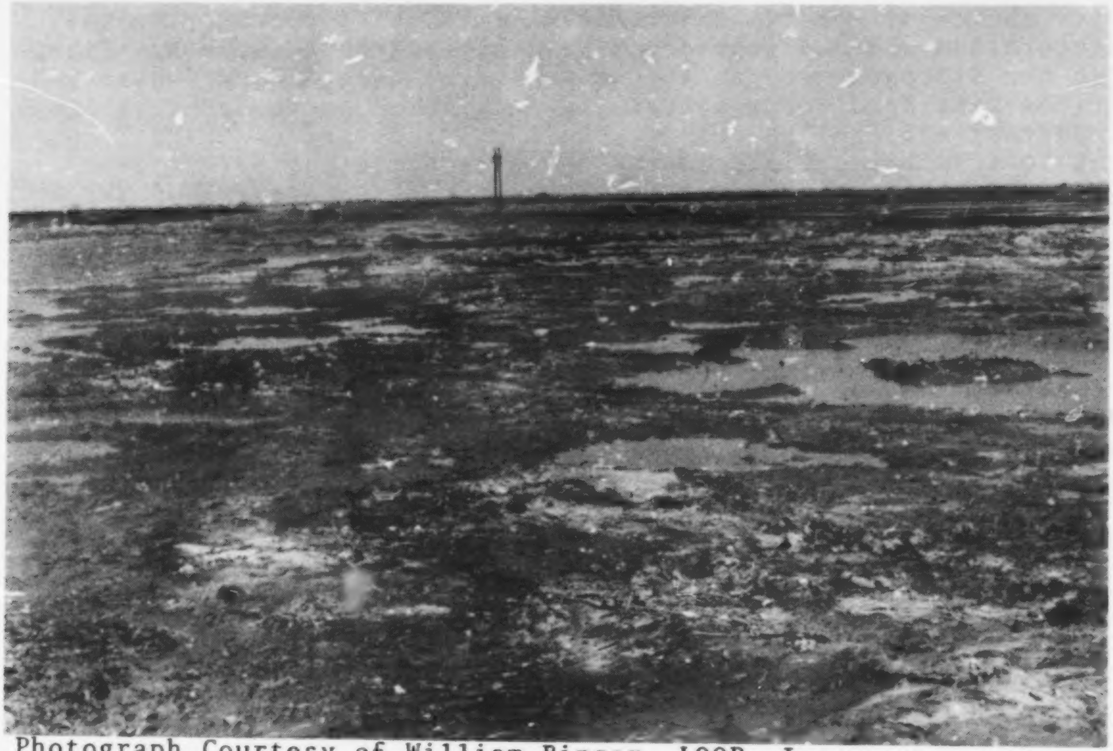
* W.P. Binger, Louisiana Offshore Oil Port, Inc., Harvey, LA), 1979: personal communication.



Photograph Courtesy of William Binger, LOOP, Inc.

FIGURE 112. Refilled Section of Pipeline Trench, March 1980.

Esso's Brent field offshore in the North Sea petroleum development area. The Banff and Buchan District Council (a group of locally elected officials) acted as the coordinator of government agency and private sector responses to Shell/Esso's landfall construction application and served as the sole permitter of landfall construction and restoration activity.

FLAGS Line Siting and Regulations: Background

When Shell/Esso declared its North Sea Brent field commercial (of sufficient size to economically justify field development) in 1973, industry planning for the route to link the offshore natural gas field to land-based processing facilities began. Because of the Brent field's northern North Sea location, the St. Fergus terminal, which serves all gas fields in that development sector, was automatically chosen as the processing and distribution location, and therefore the landfall, for the natural gas pipeline.

The St. Fergus Terminal: British Gas Corporation (BGC), which has a monopoly over gas distribution in the U.K., has, by its choice of coastal distribution terminal locations, largely determined where offshore gas will be landed in the U.K. Prior to the discovery of gas in the northern North Sea, offshore gas finds were handled at processing facilities on the central and southeastern English coast. The 1972 discovery of natural gas at Total's Frigg field in the northern North Sea development sector, however, caused British Gas to begin a search of the northeast Scottish coast for a new, more northerly site for gas processing facilities. A site large enough to handle BGC's compression and distribution facility, along with Total's separation and metering facilities, and with excess area available to handle future far northern offshore gas finds was required. Two sites fulfilling these basic requirements were located; the 500 acre site at St. Fergus, Aberdeenshire, four miles north of Peterhead was chosen.*

The first offshore pipelines landed at St. Fergus were two 32-inch diameter lines from Total's Frigg field which were installed in 1974-75. (This installation is described in detail in Chapter 4.) When Shell/Esso began development of their transportation and onshore facility planning for Brent field natural gas, St. Fergus was immediately assumed to be the landside destination. As the Shell/Esso processing facility was to be constructed just north of the existing St. Fergus terminal, a site about 150 meters (500 feet) north of the Frigg landfall was chosen for the landfall. The locations of the St. Fergus terminal, and Frigg and Brent offshore fields, are illustrated in Figure 113.

Obtaining FLAGS Pipeline Landfall Permits: British government organization places permitting control over local planning and development with district councils -- groups of elected officials which function at a level roughly equivalent to U.S. municipal governments. Larger scale strategic planning projects, such as those dealing with water supply and transportation plans, are evaluated at a regional level; those projects determined to be in the national interest are addressed directly by the British National Government.

Shell/Esso applied for FLAGS line landfall installation permits to Banff and Buchan District Council in December 1975. After consultation with other appropriate government agencies and interested environmental groups, approval was given for the project to proceed. The permit -- including construction and restoration stipulations designed to minimize environmental effects -- was issued in April 1976, approximately five months after initial permit applications were made.

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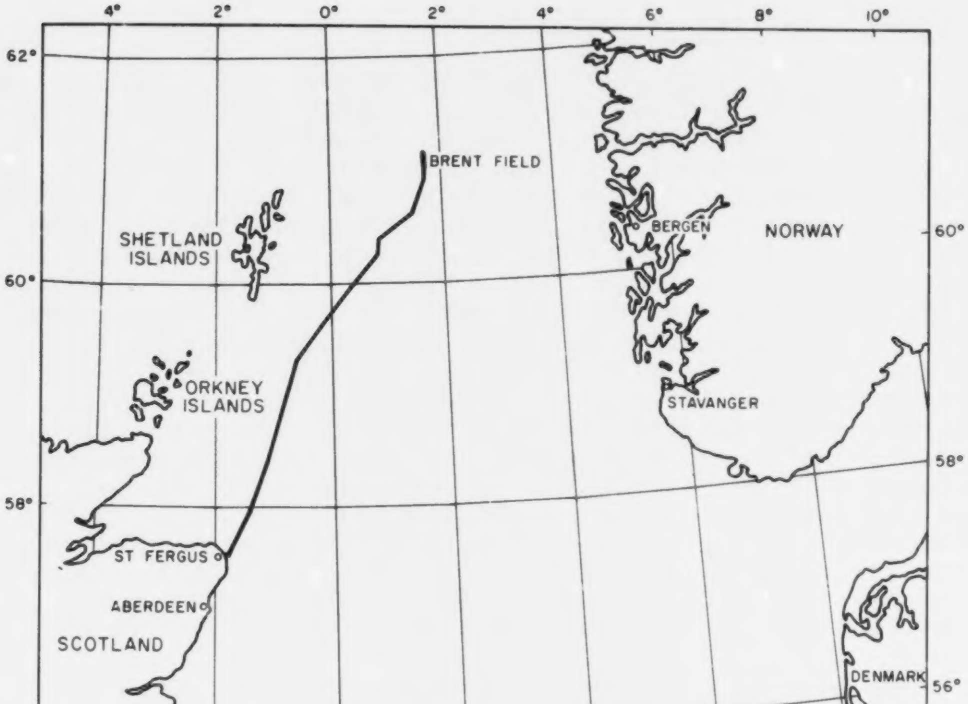
* A complete description of the St. Fergus terminal site selection process is provided in NERBC, 1979, pp. 24-25.


4°
2°
0°
2°
4°
6°
8°
10°
62°
60°
58°
56°
54°
52°
BRENT FIELD
SHETLAND ISLANDS
BERGEN
NORWAY
ORKNEY ISLANDS
STAVANGER
ST FERGUS
ABERDEEN
SCOTLAND
DENMARK
EDINBURGH
HULL
ENGLAND
THE NETHERLANDS
GT YARMOUTH
WALES
AMSTERDAM
THE HAGUE
LONDON
FIGURE 1
LOCATION OF THE FLAGS GASLINE
0
100
200
300 kilometres

Source: Shell/Expro, 1977, p.2.

FIGURE 113. Location of Frigg and Brent Fields and St. Fergus Terminal.

Pipeline Installation*

Project Facilities: The FLAGS pipeline is a 450 kilometer (280 mile) 36-inch diameter pipeline which links the offshore Brent field to Shell/Esso's separation and metering facility at St. Fergus. The steel pipeline is 0.867 inches thick and is coated with concrete 113 millimeters (mm) (4.5 inches) thick from the St. Fergus facility to a point approximately 2500 meters (m) (1.6 miles) offshore; for the next 1500m (1.6 miles), it is 90 mm (3.75 inches) thick. Thereafter, the concrete coating's thickness is further reduced. At the separation facility, the large quantities of natural gas liquids associated with the Brent field's "wet" natural gas stream are separated. The extracted gas liquids -- ethane, propane, butane and natural gasoline -- are expected to be transported via a smaller diameter pipeline to a proposed gas liquids plant and export terminal south of St. Fergus. (Until completion of this fractionation plant, some of the liquids will be piped directly to a nearby power plant.) The methane (natural gas) then passes to the adjoining British Gas Pumping and Distribution Terminal, where it is odorized and pumped into trunk lines linking the St. Fergus terminal to BGC's main distribution system (NERBC, 1979).

The Landfall Setting: The FLAGS pipeline landfall is on a steep, highly dynamic, sand beach whose profile changes with tides and seasons. The beach is backed by dunes up to 16 meters (50 ft) high, with steep front slopes (up to 20 degrees) and gentler (10 to 12 degrees) backslopes. Landward of the dunes is a seasonally flooded wetland (known as the "Winter Loch") which is generally submerged from November to April. Behind the Winter Loch is another dune ridge which is lower and more mature, backed by an old glacially deposited escarpment. Landward about 500 meters from the waterline is the St. Fergus terminal. Figure 114 illustrates the relative locations of the landfall, the terminal and these coastal features; Figure 115 shows landfall morphology in cross section. Figure 116 illustrates the beach and dunes.

Landfall Installation: Shortly after receiving permit approval in April 1976, preparation of the landfall site for the pipeline pull began. A sheet pile cofferdam, six meters (20 feet) wide and with an average four meter (13.2 foot) depth, was constructed from the waterline to a point approximately 50 meters (165 feet) landward, just behind the first dune ridge.**

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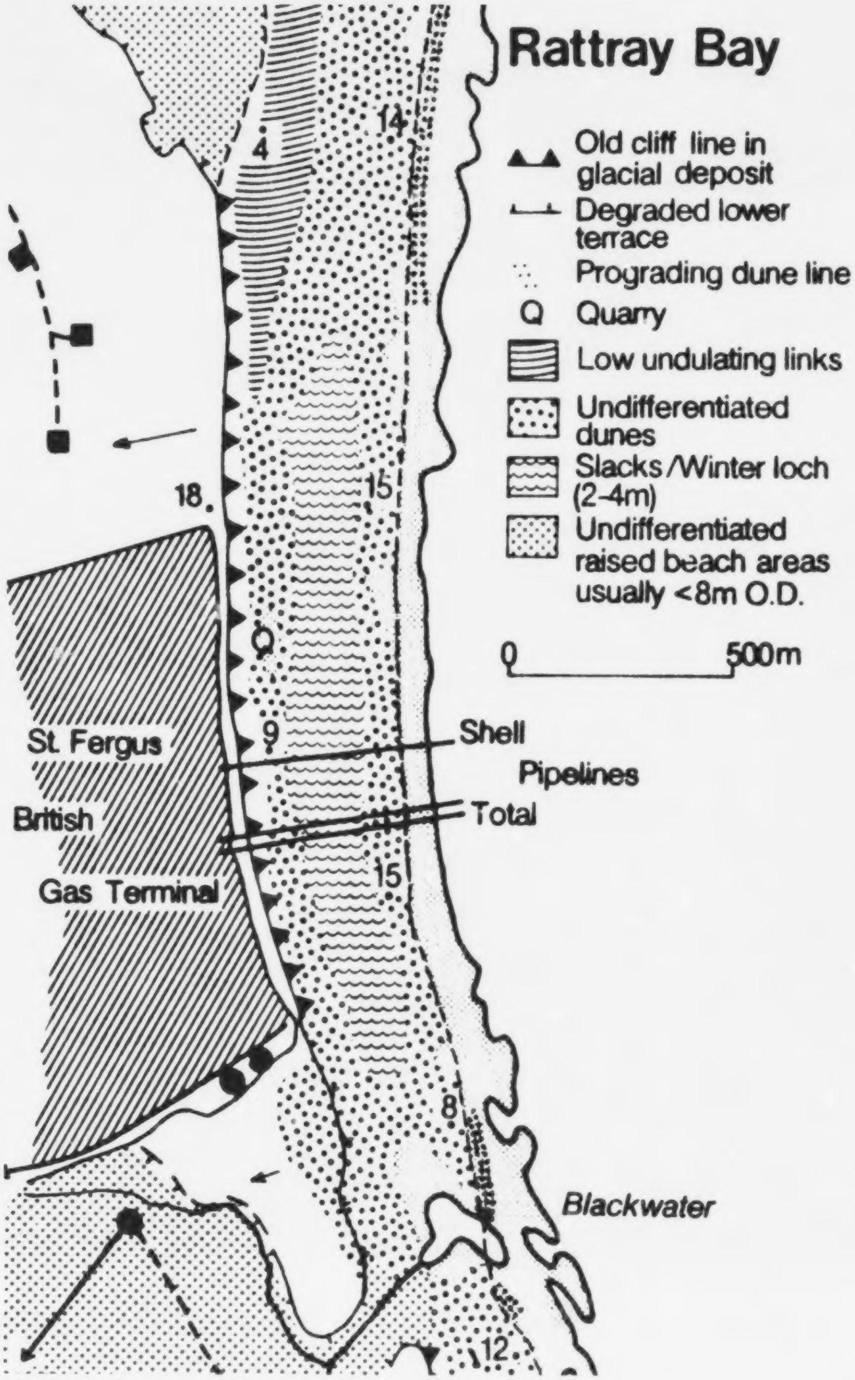
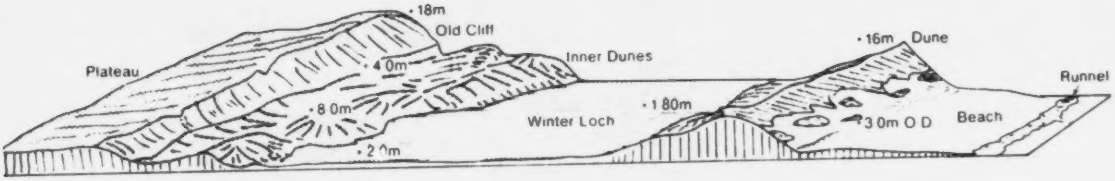
* Technical information on the FLAGS line was provided by H.E. Quattlebaum, (Esso Europe, London, England), 1979: personal communication, except where otherwise noted.

** J.M. Reynolds, (Land & Marine Engineering Ltd., Merseyside, England), 1979: personal communication.


Rattray Bay
Old cliff line in glacial deposit
Degraded lower terrace
Prograding dune line
Q Quarry
Low undulating links
Undifferentiated dunes
Slacks/Winter loch (2-4m)
Undifferentiated raised beach areas usually <8m O.D.
0
500m
14
4
18
15
Q
9
Shell
Pipelines
Total
St. Fergus
British
Gas Terminal
15
8
Blackwater
12

Source: Ritchie et al., 1979, p. 228a.

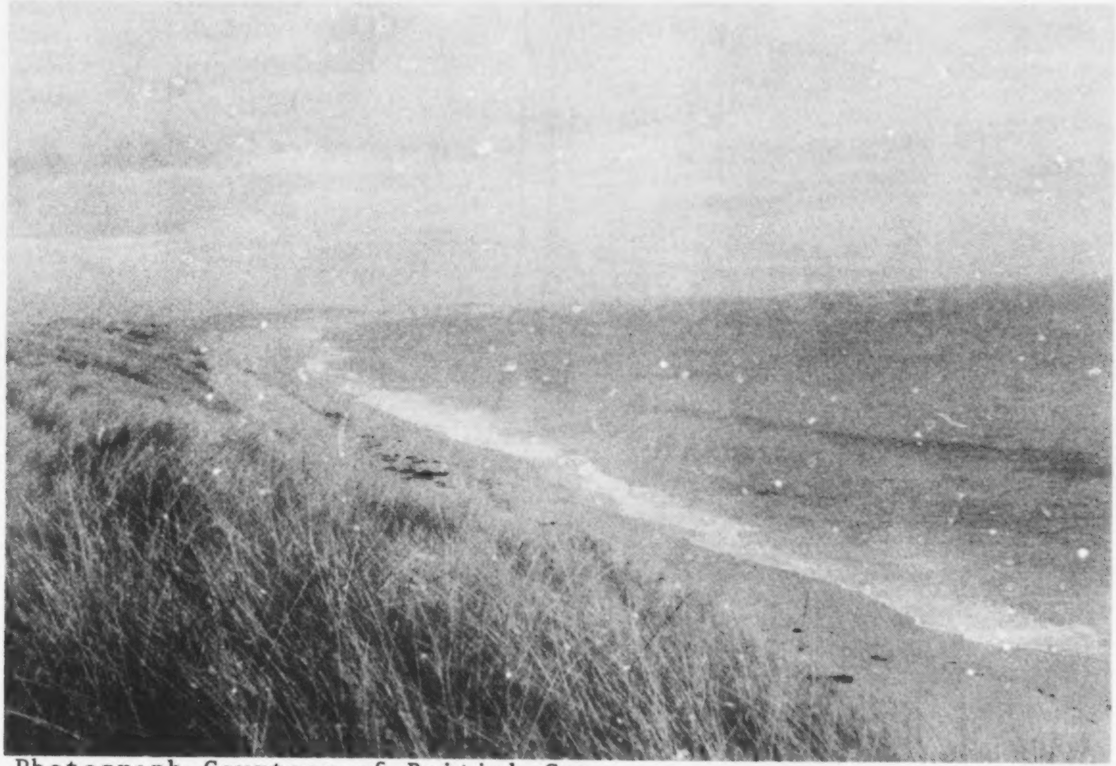
FIGURE 114. Coastal Features at St. Fergus Site.



• 18m
Old Cliff
Inner Dunes
Plateau
• 4 0m
• 8 0m
• 2 0m
Winter Loch
• 1 80m
• 16m
Dune
3 0m O D
Beach
Runnel

Source: Ritchie et al., 1979, p. 228a.

FIGURE 115. The morphology of the St. Fergus landfall showing the relationships of the various land forms. The winter loch is a seasonal wetland.



Photograph Courtesy of British Gas.

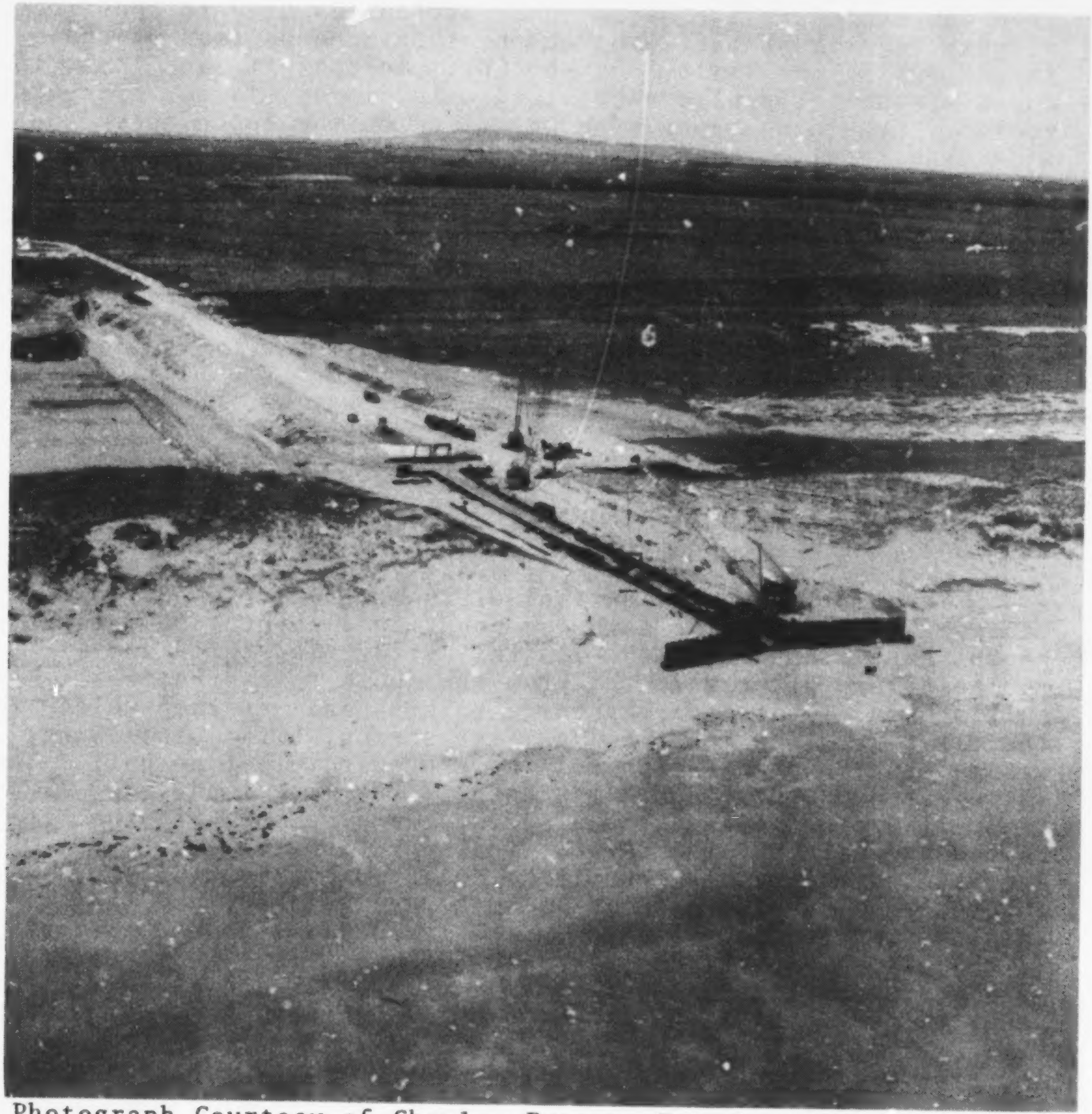
FIGURE 116. A View of the Large 16 Meter High Dunes at St. Fergus.

Conventional land-based excavation equipment was used to dig the pipeline trench.

To facilitate restoration, materials from various points along the trench were excavated and stored separately. Beach sand was stored in two ways. One portion was used to construct a jetty to prevent refilling of the surf zone portion of the trench during the laying of the line. To prevent sand loss, the edges of the jetty were stabilized with riprap (large, irregular rocks). Remaining beach sand was piled on the beach above the high tide level. Excavation through each of the dune ridges occurred in two phases. First, the upper "topsoil" layer -- 25 centimeters (about 10 inches) from the first dune line and 50 centimeters (cm) (about 20 inches) from the second, more mature and densely vegetated dune line -- was excavated and stored in separate piles behind the first set of dunes. The remaining sand was then removed and used to construct a causeway about 15-20 meters (50 to 60 feet) wide and eight meters (26.4 feet) high across the winter loch, second dune ridge and cliff line back to the terminal perimeter. The causeway was used as the onshore staging area for the pull and as the sole "roadway" link for construction machinery moving from the terminal to the beach. Figure 117 shows the landfall prior to pipeline installation; Figure 118 shows the causeway as viewed from the terminal.

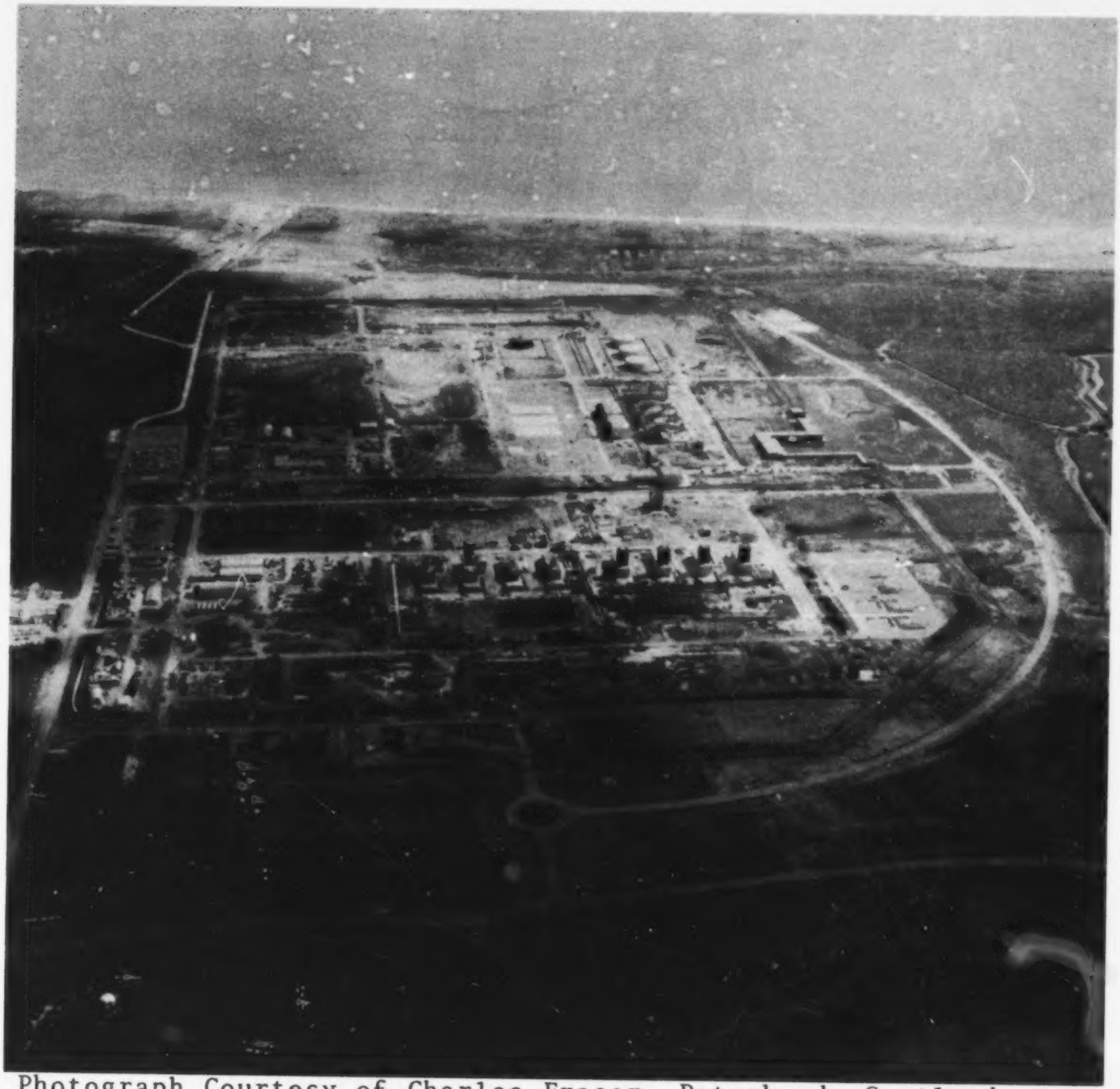
In early July, two pulling winches were set up on the causeway and a pipeline laybarge positioned about 1400 meters (4620 feet) offshore of the landfall site. Two three and one-half inch wires were run from the shore to a pipeline pulling head located on the barge. This head was then welded to the first pipeline joint and a first string, five joints long, was made up in preparation for the shoreward pipeline pull. The shore-based winches then began to pull the line landward. As the pull proceeded, additional joints were welded onto the line, coated and laid off the barge. Buoyancy tanks, which facilitated the pull by counterbalancing the weight of the concrete-coated pipe (400 lb/ft sumberged weight), and thus keeping pipeline lay stresses within safe limits, were attached to the pipe at specified intervals. The entire 1500 meter shore pull was accomplished in 48 hours. Figure 119 shows the prepared trench with the pipeline pull underway.

After the pull was completed, the buoyancy tanks were removed. Prior to beach and foredune restoration, an additional 12-inch diameter plastic pipeline was placed in the trench. This pipeline was intended to be used during the Winter Loch excavation to drain water pumped from the trench and water used to pressure test the line before use for gas transmission. The trench was then immediately refilled with original material from the waterline through the first dune ridge.



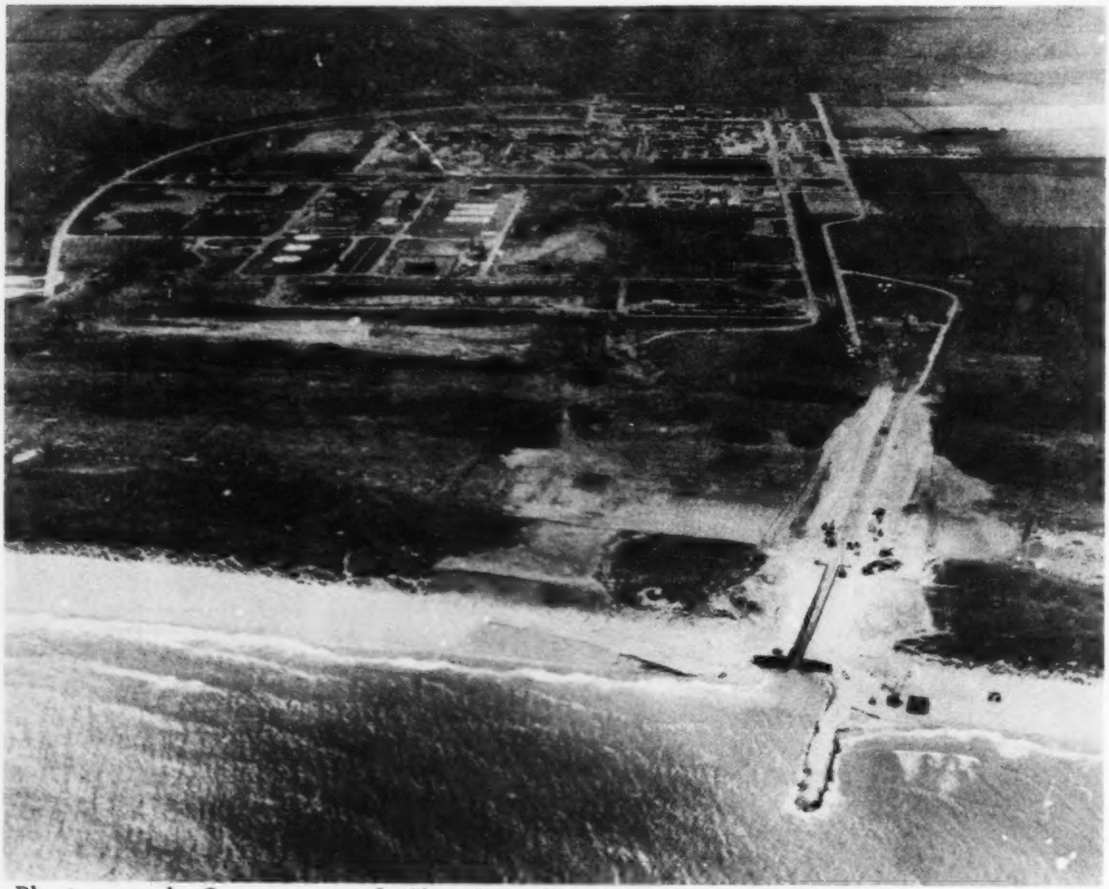
Photograph Courtesy of Charles Fraser, Peterhead, Scotland.

FIGURE 117. Landfall Prior to Pipeline Pull.



Photograph Courtesy of Charles Fraser, Peterhead, Scotland.

FIGURE 118. Terminal and Causeway (Laybarge in Distance).



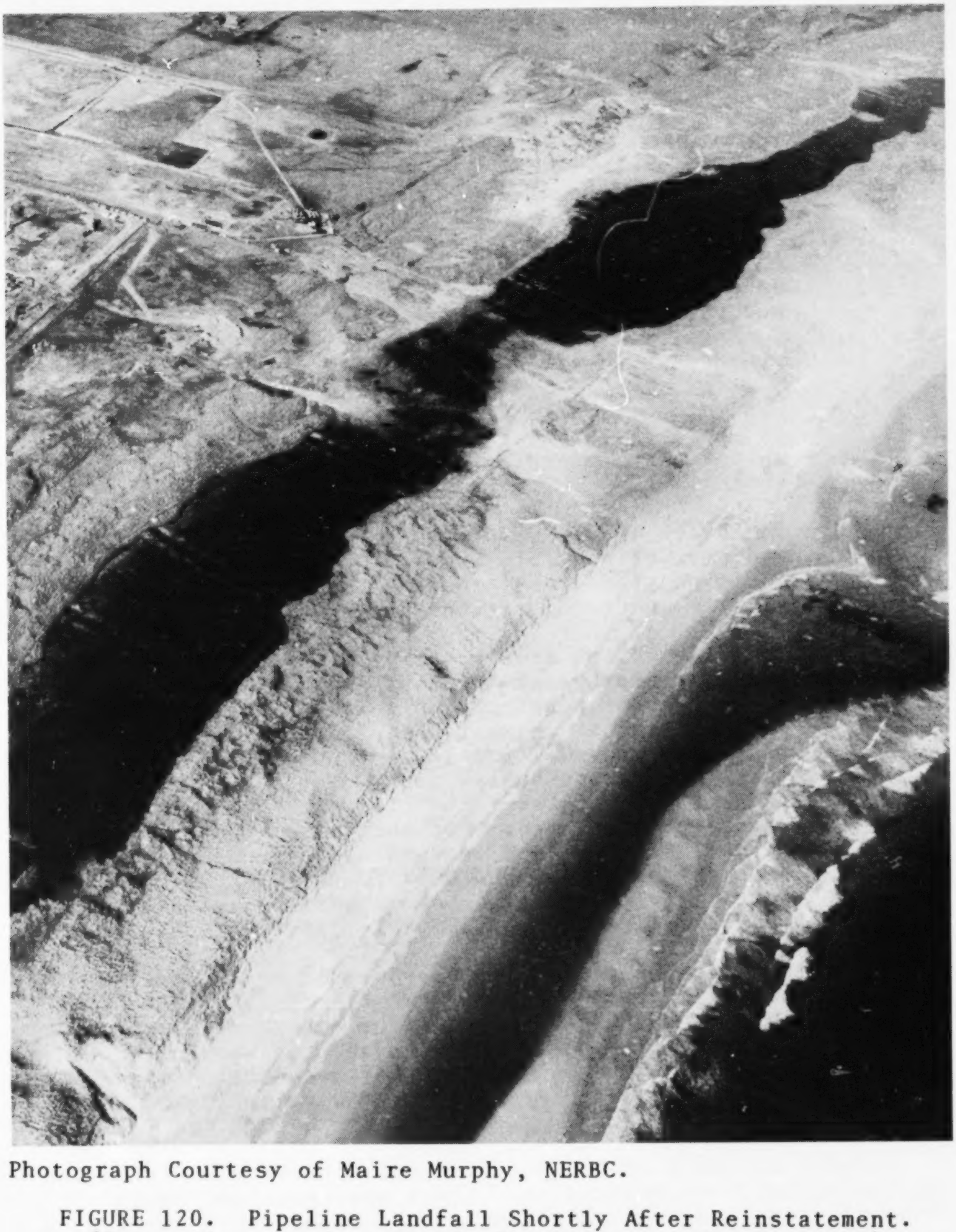
Photograph Courtesy of Charles Fraser, Peterhead, Scotland.

FIGURE 119. Pipeline Pull Underway.

Conventional land-based techniques were used to excavate the trench, lay the pipe, and refill the trench along the remaining right-of-way across the loch up to the terminal site. Figure 120 shows the landfall shortly after the installation was completed.

Pipeline Landfall Restoration Techniques and Regulations

The FLAGS landfall area -- particularly the winter loch -- is considered an area of special ecological interest both by the Scottish Wildlife Trust and the Royal Society for Protection of Birds. Therefore, as project planning progressed, both Shell/Esso and the regulating agency -- Banff and Buchan District Council -- paid particular attention to the selection and use of methods for landfall restoration which would minimize long-term damage to the ecological system.



Photograph Courtesy of Maire Murphy, NERBC.

FIGURE 120. Pipeline Landfall Shortly After Reinstatement. (Frigg lines in foreground, FLAGS line slightly north.)

Preinstallation Surveys: When Shell began planning the FLAGS pipeline landfall, they contracted with University of Aberdeen scientists to prepare an environmental impact statement of potential pipeline effects at the St. Fergus site. In November 1975, a report, "Environmental Appraisal of Pipeline Landfall Site Area at St. Fergus (Rattray Bay)," was completed. As part of this assessment, an ecological survey of the area was performed which describes these landfall features:

- Plant Species -- a rich and diverse flora is evident in the area. *Ammophila* (Marram grass) dominates the dune vegetation. Other dune flora include red fescue and various mosses. Landward, *Ammophila* becomes less dominant and other grasses and mosses become the more frequently observed species.

- Concrete pillboxes (remnants of World War II) located in small cliffs near the terminal site are considered as potential breeding sites for Fulmars -- a common seagull.

- The beach and seaward side of the dunes are eroding and are periodically undercut by waves and wind. In addition, the dunes are affected by slumping, wind erosion and redeposition; and

- The winter loch area was determined to be the area of greatest biological interest and had the greatest potential for construction-related damage. The winter loch is unusual in that the periodic flooding is the result of ground water level fluctuations rather than ocean inundations which might be the expected source of water. Therefore, the flora are brackish/fresh water species rather than the saline-tolerant species normally encountered in coastal wetlands. The "spongy" nature of the wetland soil makes it particularly sensitive to compaction by construction machinery* (Walton and Ritchie, 1975).

Another section of the EIS was devoted to an assessment of the anticipated effects of cutting the trench and recommendations of methods to minimize damage from construction. Possible effects were considered based on location. It was felt that the beach itself would show no long-term environmental damage from installation, provided the majority of the orignal sand was returned to the trench immediately upon completion of the pull. Landfall installation was projected to cause greater potential risks to the dune ridge and winter loch.

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* A later analysis included additional ecological information on the winter loch vegetation. Flora was described as an unusual grassland type which supported, among other species, a rare sedge (Ritchie, 1979).

The dune ridge was felt to be a major zone of potential disturbance from pipeline installation due to the large quantities of excavated sand requiring storage and the difficulties associated with restoration due to the dune's naturally dynamic and unstable state. To minimize both effects, a narrow trench cut, maintained by Crelawn -- a bituminous stabilizing spray -- to prevent slumping and wind erosion, was recommended. A specific method of sand storage based on segregation of surface and lower layers was also suggested. Various storage sites for the large quantities of lower layer sand were considered, including the beach or directly behind the dune. The third and favored storage possibility was on that area of the winter loch previously disturbed (and at that point unrecovered) by Total's Frigg lines installation. To minimize sand loss through wind erosion, a storage pile with a maximum height of 5 meters (16.5 feet) above surface level and use of Crelawn spray were also recommended.

The winter loch area was recognized as the most ecologically sensitive to pipeline installation activities. Therefore, construction-related recommendations focused on minimizing the amount of damage to this area by limiting vehicle traffic to specific corridors and prohibiting any form of materials (e.g., sheet piling) storage. Maintenance of original drainage patterns was also stressed. Finally, it was emphasized that any water pumped from the pipeline trench should be discharged on the beach rather than onto the surface of the winter loch.

Similar procedures to those recommended for the first dune line were also recommended for the second dune ridge. Other general recommendations included minimizing vehicular traffic to the narrowest possible areas, marking and/or fencing those areas where traffic would be allowed, and controlling waste material dumping at the site.

The final section of the EIS described recommended methods for restoration of the area upon completion of the pull. Goals for the restoration were to recreate a stable environment -- physically, ecologically, and aesthetically similar to the distrubed area's original condition and to the surrounding area. Recognizing that the original conditions of the area were the result of centuries of natural processes which would be impossible to exactly duplicate, the report concludes that, "The objectives must be to produce land forms which have similar water table and soil conditions" (Walton and Ritchie, 1975).

To achieve these goals, the following restoration methods were recommended for returning the area to its original topographic profile:

- All affected areas from the first dune line landward should be returned to original profiles using original materials excavated from the area and covered with "topsoil" for stabilization.
- The face of the first dune line should be stabilized with a gabion wall buried within the dune ridge. This wall would act as a fail-safe device to protect against breaching in the event of unusually high tides and storm conditions. Additional stabilization with fishing nets was also suggested.
- The pipeline trench through the beach should be refilled with sufficient cover to prevent pipeline exposure. The depth of cover should be determined based on the winter beach profile which is much lower and flatter than the summer beach profile.

Recognizing that the revegetation effort would need to be developed based on the extent and location of construction-related damage, only one specific recommendation -- hand planting Marram grasses (Ammophila) on the dune face, crest and ridge -- was made. Although recognized as time consuming and likely to be only partially successful, it was felt that this was the best way to insure at least partial dune revegetation. Stipulations of other specifics for revegetation (types of grasses used for reseeding, and use of fertilizers and physical protection devices, such as snow fences) were deferred until more specific site evaluation work had been completed. Periodic inspection visits to the site to assess restoration success were also suggested.

Finally, the report emphasized the importance of maintaining good communications with local planning officers to the overall success of the installation and restoration efforts.

Pipeline Installation Permits:* In December 1975, Shell/Esso applied to Banff and Buchan District Council for the landfall permit to install the FLAGS pipeline at St. Fergus. The application contained, in addition to technical information on the pipeline installation, the environmental impact statement prepared by the University of Aberdeen. The Council notified a number of potentially interested agencies and public groups seeking their comments on the permit application. Among the environmentally related groups consulted were the Buchan Society for Conservation, the Aberdeen branch of the Conservation Society, the Nature Conservancy Council, the Scottish Wildlife Federation and the Royal Society for the Protection of Birds. Additionally, an ad hoc group of interested scientists and geographers at the University of Aberdeen, formed when petroleum-related development had begun in the area, acted (as they had for other projects) as an overseer and "watchdog" of the project to insure that environmental concerns were properly addressed.

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* The information on permit development and oversight on implementation of its stipulations was provided by Maire Murphy (NERBC, Boston, MA) who, at the time of installation, was staff to the Banff and Buchan District Council.

Comments received, along with the recommendations for installation and restoration outlined in the EIS, served as the basis for development of a set of permit stipulations for the FLAGS line installation. A draft approval of the permit application containing these stipulations was released on April 26, 1976 by the Banff and Buchan Council and a three week comment period allowed for appeals by the developer or other interested parties. Having received no appeals, the permit regulating installation of the FLAGS pipeline from the low watermark to the boundary fence of Shell's proposed gas plant became effective May 17, 1976. A complete listing of permit stipulations are presented in Table 5. Reasons for each stipulation are also presented (in italics).

The Banff and Buchan Council had two methods available for the enforcement of these permit stipulations. First, the Council had oversight authority for the project including the statutory power to enforce regulations by stopping the project if unsatisfactory, contracting with others to complete the job, and billing the developer for the work. Second, to insure complete restoration, the Council required Shell/Esso to put up a half-million dollar bond with all the permit's conditions translated to bond stipulations. (The complete legal agreement between the Council and Shell U.K. Limited for landfall installation and restoration is presented in Appendix B.)

Pipeline Installation: After permit approval, the developer was required to consult with the Council if alterations in original plans were necessary or desirable. One of the major changes in installation was that of the construction of the causeway. Originally, all excavated materials' storage on the Winter Loch was to be limited to that area of the wetland already disturbed the previous year by the Frigg line installation. Once construction began, however, the pipeline installation contractor suggested constructing a causeway across the loch with excavated materials. Because this method would limit a major potential cause of Winter Loch damage by restriction of all construction activity to this one area,

TABLE 5.

PERMIT STIPULATIONS FOR FLAGS PIPELINE

A longitudinal profile of the entire Winter Loch bottom to be submitted to the Director of Planning and Development prior to the commencement of any works.

To facilitate monitoring and ensure satisfactory restoration.

Details of method of pipe pull to be used (whether offshore or onshore) to be agreed with the Director of Planning and Development prior to the commencement of any works.

To facilitate evaluation of the input on the site and the efficacy of proposed protection and restoration measures.

Profiles of the winter beach, sandhills and landward escarpment to be submitted to the Director of Planning and Development.

To facilitate monitoring and ensure satisfactory restoration.

Side slopes of the dune cut to be sprayed with bitumen compound on exposure.

To minimize wind erosion.

Sand removal from the dune area to be in two stages:

(a) the top 25 centimeters of sand and vegetation to be stripped and stored in a clearly defined area separate from any other topsoil or sand spoil.

(b) the remainder of the sand from the dune area to be stored in that part of the Winter Loch area that has already been damaged and partially restored.

To conserve the organic material which will be required for the restoration process, and to minimize disturbance to the Winter Loch area.

The top 50 cm of vegetation and topsoil from the sandhills and landward escarpment area to be removed and stored in a clearly defined area separate from any other topsoil or sand spoil.

To conserve the organic material which will be required for the restoration process.

The remainder of the material excavated from the sandhills and landward escarpment areas to be stored as specified in Condition 7(a).

To minimize disturbance to the Winter Loch and dune areas.

(continued)

TABLE 5. (continued)

Spoil to be stored in the Winter Loch area in such a manner as to permit longitudinal movement of surface water.

To minimize ecological damage to the Winter Loch.

Stored sand heaps to be not greater than 5m above surface level and the surface of any stored sand to be lightly sprayed with bitumen compound.

To stabilize sand.

General storage of materials, machinery and equipment to be confined to the upper plateau surface at the extreme west side of the site.

To minimize disturbance to the dunes and Winter Loch area.

Apart from sand and topsoil which is to be stored as indicated in Conditions 7, 8, and 9, no storage to be permitted in the Winter Loch area.

To minimize disturbance to the Winter Loch area.

A system of refuse collection and disposal to be implemented to the satisfaction of the Director of Environmental Health.

To prevent indiscriminant dumping of waste on site.

Any water pumped from the pipeline trench to be discharged directly on to the beach. The Winter Loch area to be kept free of this or any other waste.

To minimize damage to the ecology of the Winter Loch.

Access tracks across the site to be limited in number and clearly defined before the commencement of any works.

To minimize disturbance to the Winter Loch and dune system.

All other areas which are to be used by vehicles to be clearly defined and marked on the site and fenced before commencement of development.

To minimize damage to the Winter Loch and dune system.

The pipe to be buried to a sufficient depth to prevent its exposure in winter conditions.

To prevent pipe exposure.

(continued)

TABLE 5. (continued)

The dune fence breach to be strengthened by the insertion, at an early stage and as an integral part of the reinstatement of the site, of a gabion wall of design and dimensions approved by the Director of Planning and Development.

To prevent sea water penetrating directly through the dunes to the winter loch and to prevent erosion of the dune cut by wave and tidal action.

After the pipe is laid, the site to be restored to its original physical state and configuration and in accordance with the contours shown in the profiles specified in Conditions 3 and 5.

To ensure satisfactory restoration.

Any topsoil to be used in restoration of the dune to be of suitable composition and depth to permit the free rooting of Marram grass.

To ensure satisfactory restoration of vegetation.

Immediately after the physical restoration of the site, the dune face, crest and ridge to be stabilized and planted with Marram grass. All other disturbed surfaces to be stabilized, fertilized and planted in accordance with a restoration program approved by the Director of Planning and Development.

To ensure satisfactory restoration.

The progress of restoration to be monitored at regular intervals and replanting carried out as necessary.

To ensure satisfactory restoration.

Existing trees to be retained and additional planting to be carried out in accordance with a landscaping plan to be submitted to the Director of Planning and Development within 3 months of commencement of development. All planting to be carried out not later than the first planting season following the commencement of works and thereafter to be maintained in accordance with the code of good forestry practice.

To ensure satisfactory restoration and maintenance.

The developer to remain responsible for the condition and satisfactory restoration of the site until vegetation is re-established and, in any event, for at least 5 years after restoration has been carried out.

To ensure satisfactory restoration and maintenance.

(continued)

TABLE 5. (continued)

After the restoration has been carried out, all artifacts, waste, rock fragments, hardcore and any other refuse or spoil to be removed from the site area or disposed of to the satisfaction of the Director of Planning and Development.

To ensure restoration of the original environment.

On completion of all site works, including those of restoration, the natural drainage system of the site to be restored.

To ensure restoration of the original environment.

Source: After Banff and Buchan Council Permit Application #B/75/P/1631, April 26, 1976.

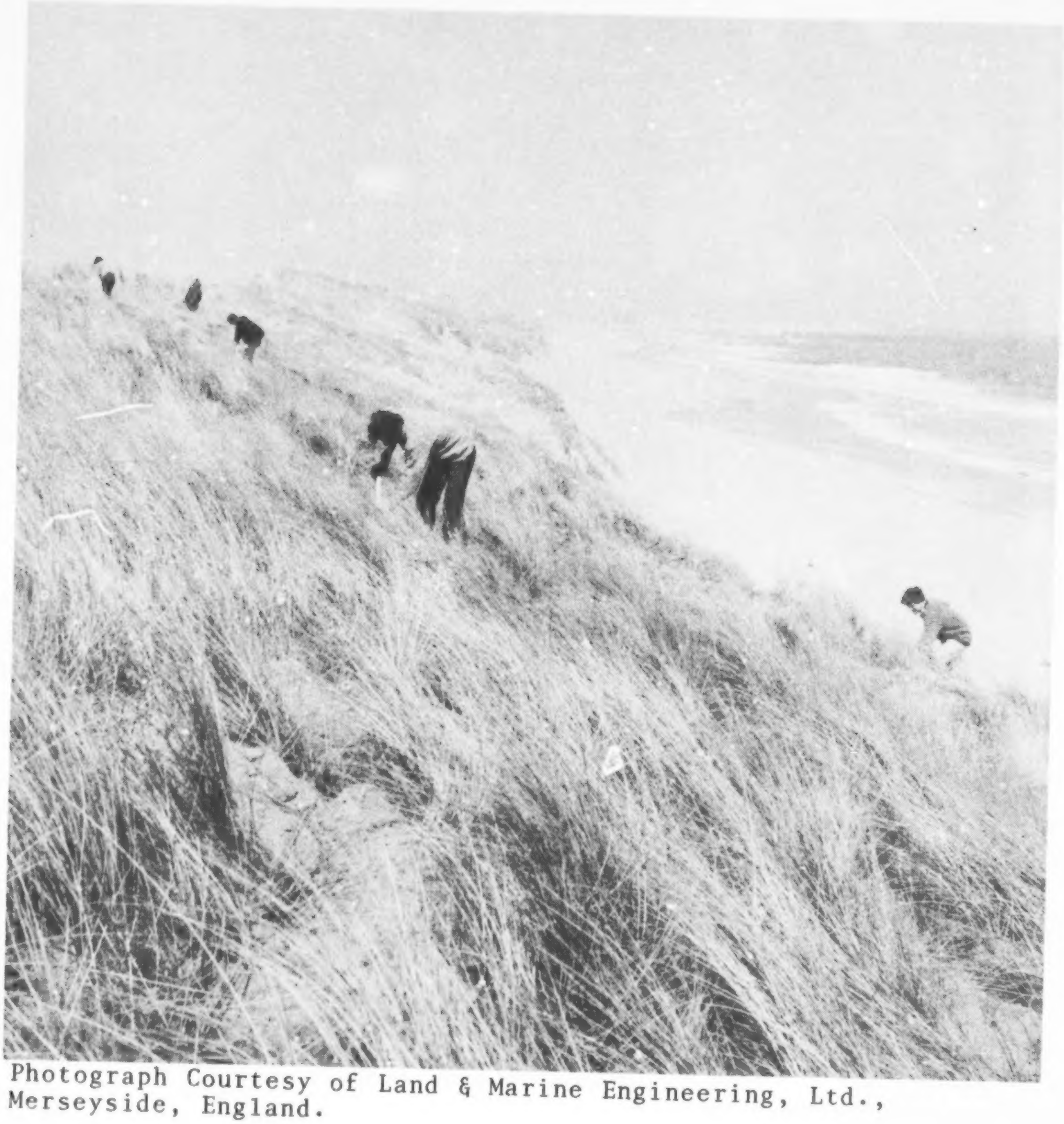
the idea was accepted as environmentally superior to the original stipulation. The Banff and Buchan District Council, therefore, readily approved the suggestion and required no formal change in the original permit. Another variation from the original plan was the placement of the additional pipe in the trench, which the contractor realized (after construction began) would be necessary to drain the trench to be excavated through the winter loch.

The success of the installation was greatly facilitated by the Council's attitude that legitimately necessary or environmentally superior methods suggested after permit approval could be accepted without undergoing lengthy legal permit alterations. This flexibility, coupled with the fact that Shell/Esso's environmental consultant was well known and highly regarded by the Council, encouraged a general spirit of cooperation between the developer and the Council.

Restoring the Dunes: The first dune line acts as a key natural topographic feature at the St. Fergus terminal due to the protection from salt water intrusion it gives to the winter loch area behind it. In its natural state, the dune line is highly dynamic and unstable; when "reconstructed" after installation, the dune structure was even more unstable. Therefore, great emphasis was placed on quick and effective stabilization measures. In autumn 1976, four inches of topsoil was placed on top of the reconstructed dune. Because successful revegetation was unlikely from fall plantings, the entire area was covered with fish net held in place with stakes to prevent overwintering erosion. Snow fences were also installed to aid in sand accretion.

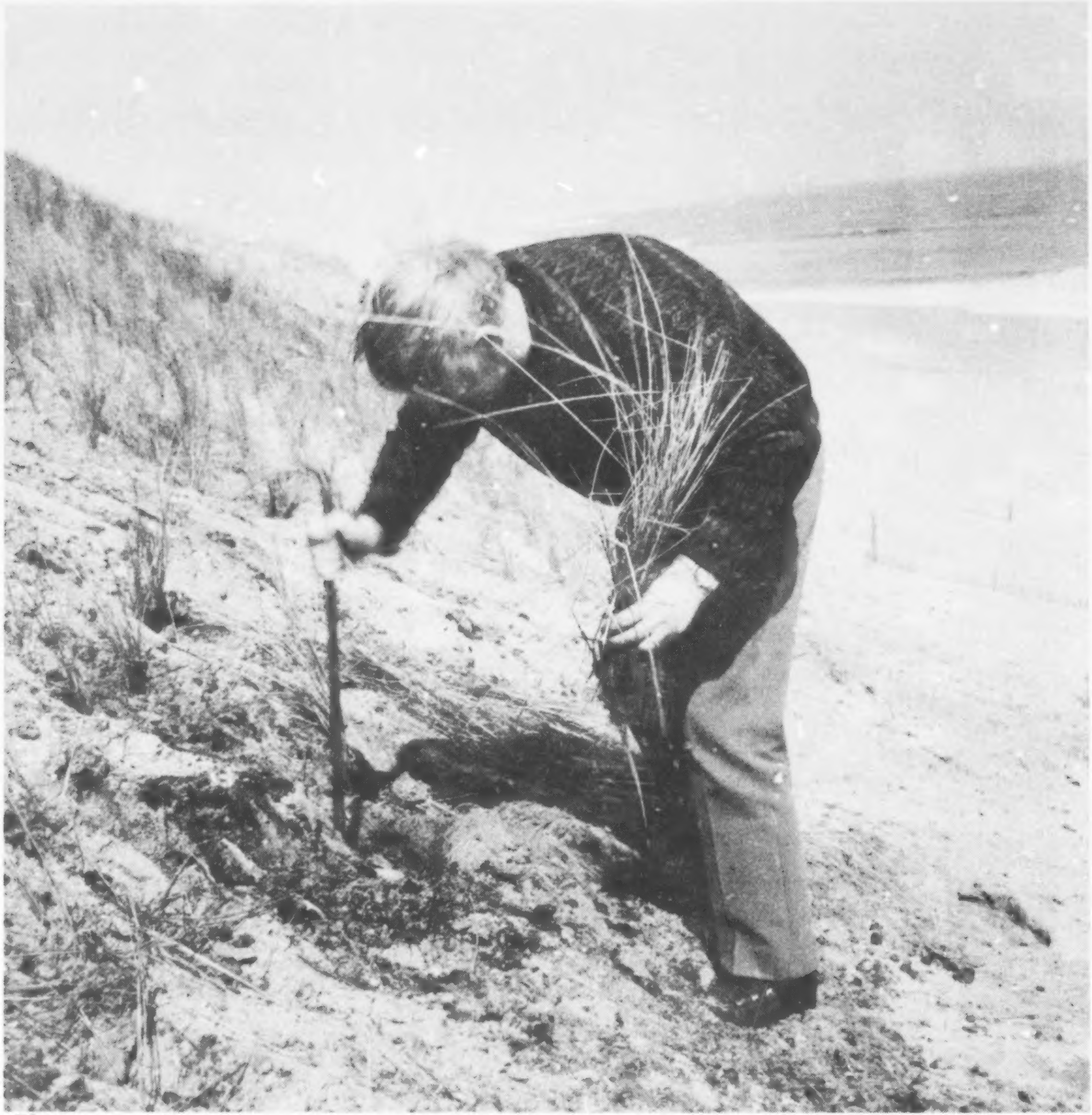
In spring 1977, hand planting of the dune face and ridge with Marram grass was undertaken by students from the University of Aberdeen. First, Marram "plugs" (small sprigs) were removed from adjacent dunes slightly to the north of the landfall. These sprigs were then transplanted at set intervals along the disturbed dune face and ridge. Figures 121 through 126 illustrate various stages in the planting operations. Two days were required to replant the disturbed area, which was approximately 150 meters (495 feet) wide.

Restoring the Landward Right-of-Way: After the pipeline trench was refilled along the remainder of the line, the area was immediately reseeded with indigneous vegetation across the winter loch and second dune ridge. This portion of the restoration was completed in fall 1976. Figure 127 is a landward view of the right-of-way taken from the first dune ridge. Shown are the Winter Loch, second dune ridge and escarpment looking towards the Shell gas plant construction site.



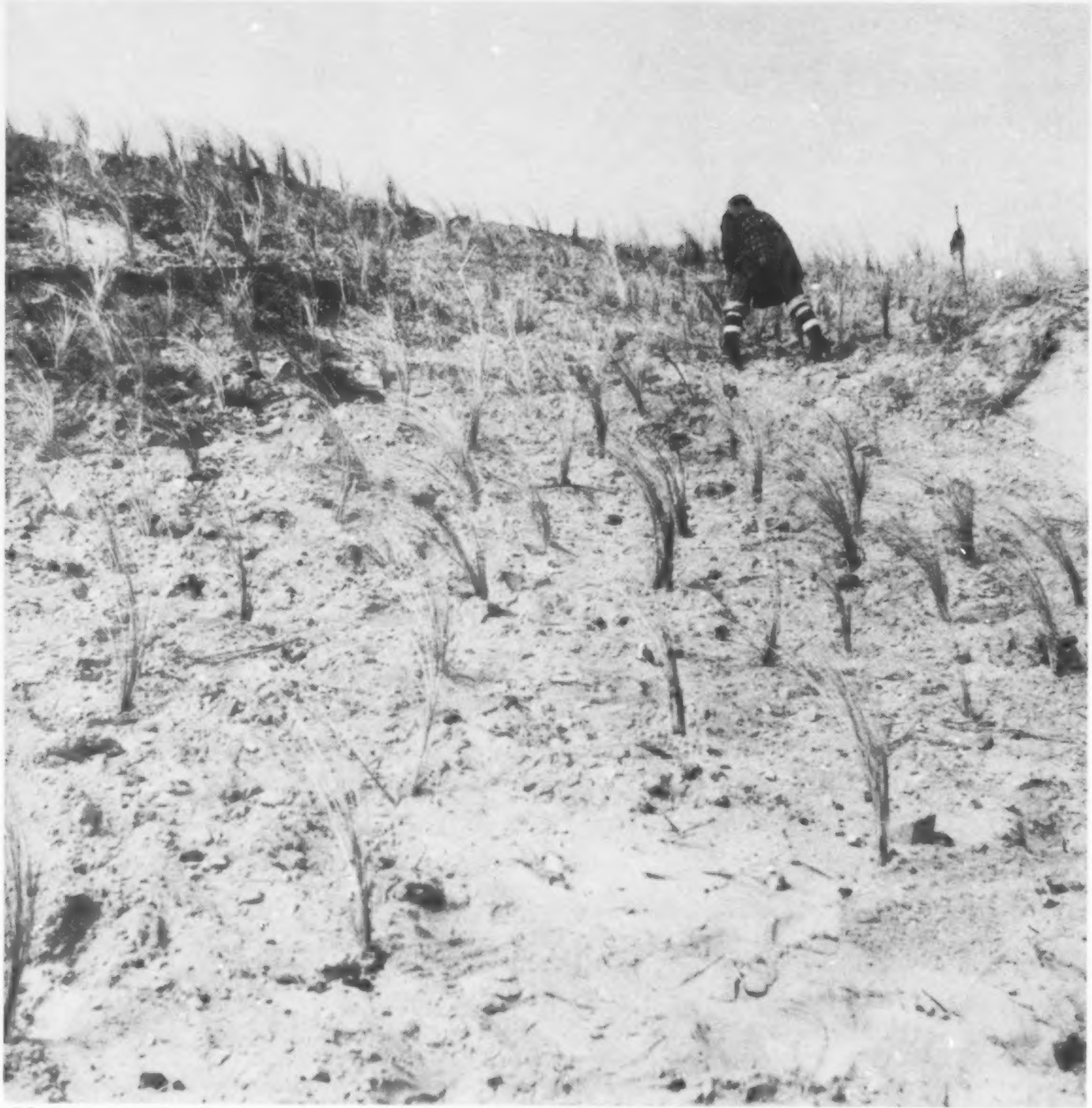
Photograph Courtesy of Land & Marine Engineering, Ltd., Merseyside, England.

FIGURE 121. Collecting Marram Grass for Transplanting. Looking south.



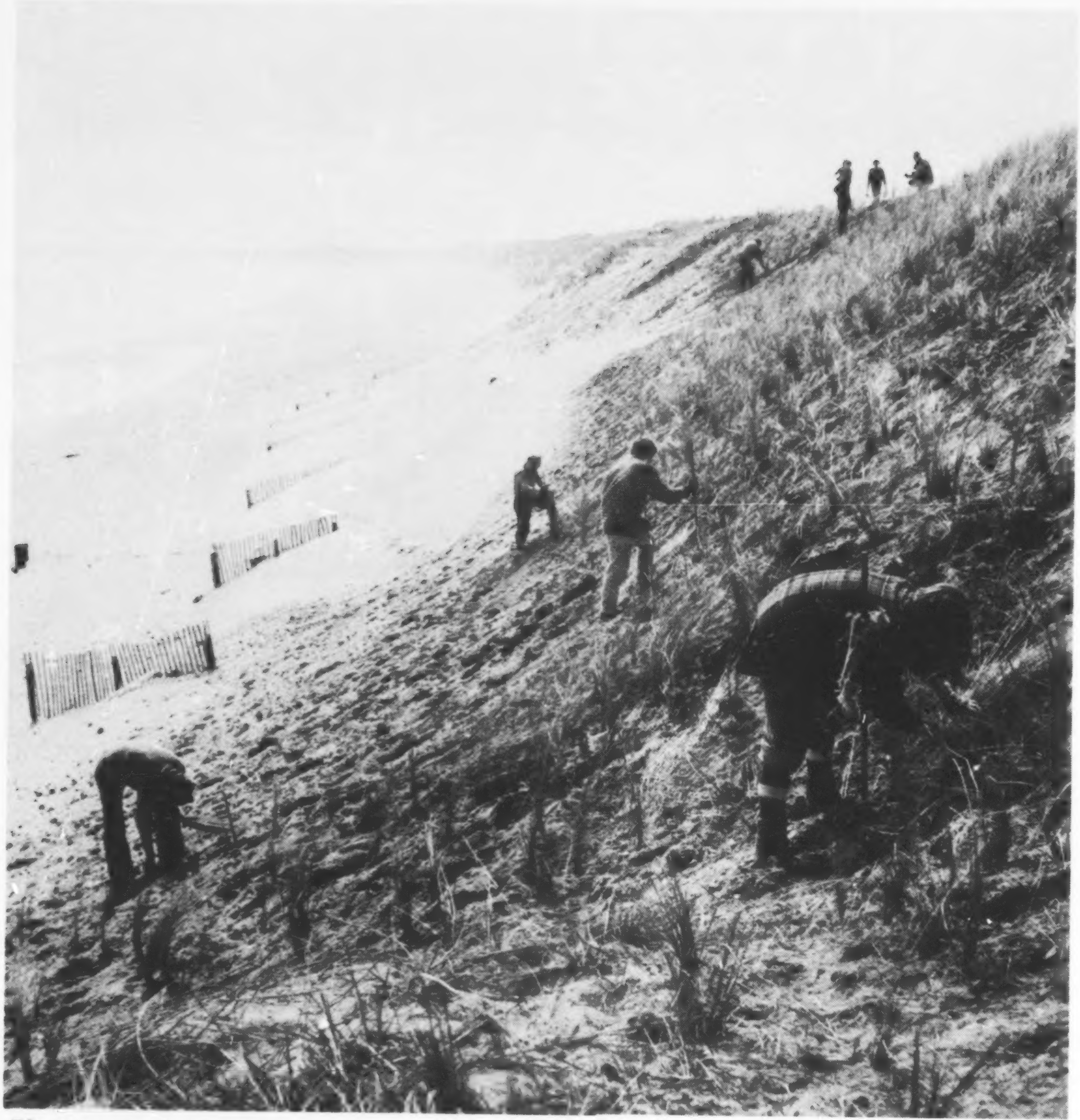
Photograph Courtesy of Land & Marine Engineering, Ltd., Merseyside, England.

FIGURE 122. Approximate size of Individual Marram Grass Plug.



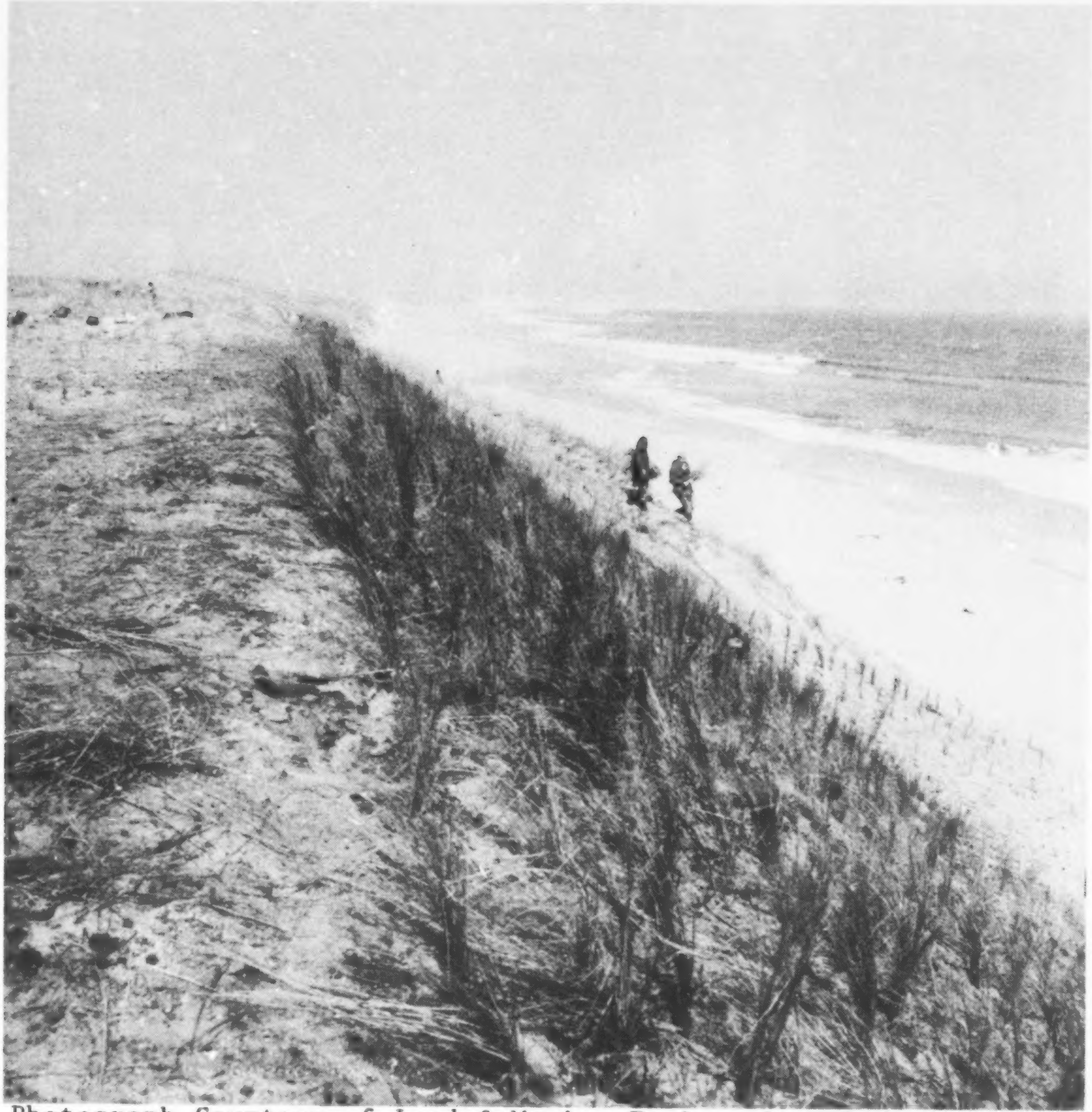
Photograph Courtesy of Land & Marine Engineering, Ltd., Merseyside, England.

FIGURE 123. Replanting Marram Grass at the Landfall. (Note approximate distribution of Marram grass plugs.)



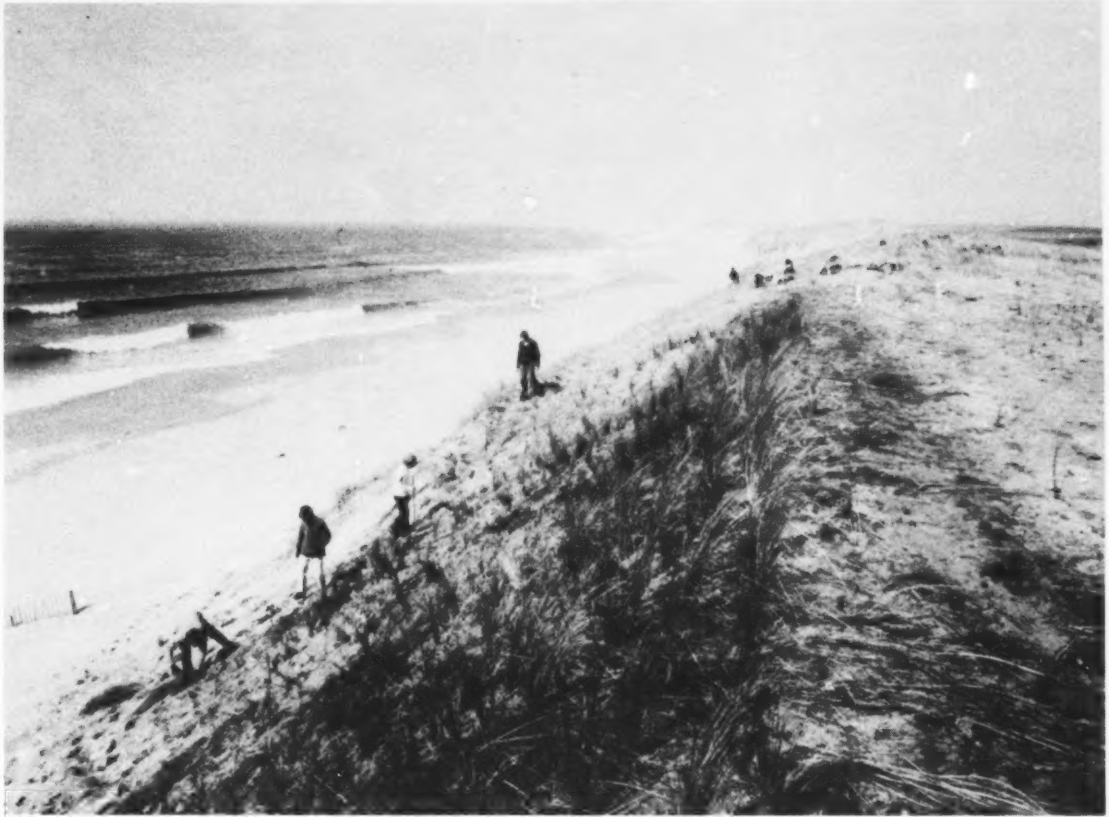
Photograph Courtesy of Land & Marine Engineering, Ltd., Merseyside, England.

FIGURE 124. Replanting Marram Grass at the Landfall. (Note snow fence accretion devices on beach.) Looking south.



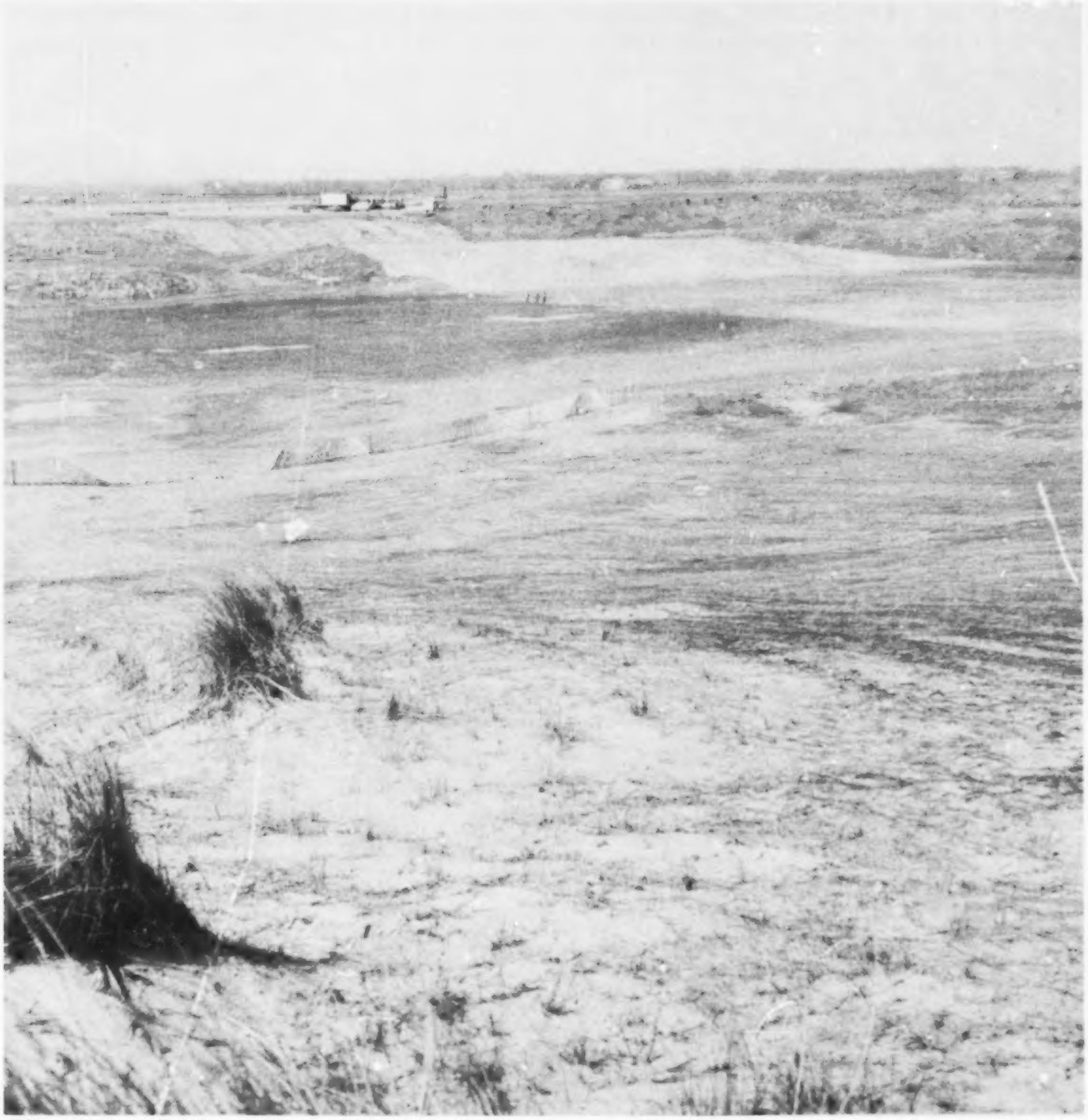
Photograph Courtesy of Land & Marine Engineering, Ltd.,
Merseyside, England.

FIGURE 125. Completed Section of Dune Replanting. Looking north.



Photograph Courtesy of Land & Marine Engineering, Ltd., Merseyside, England.

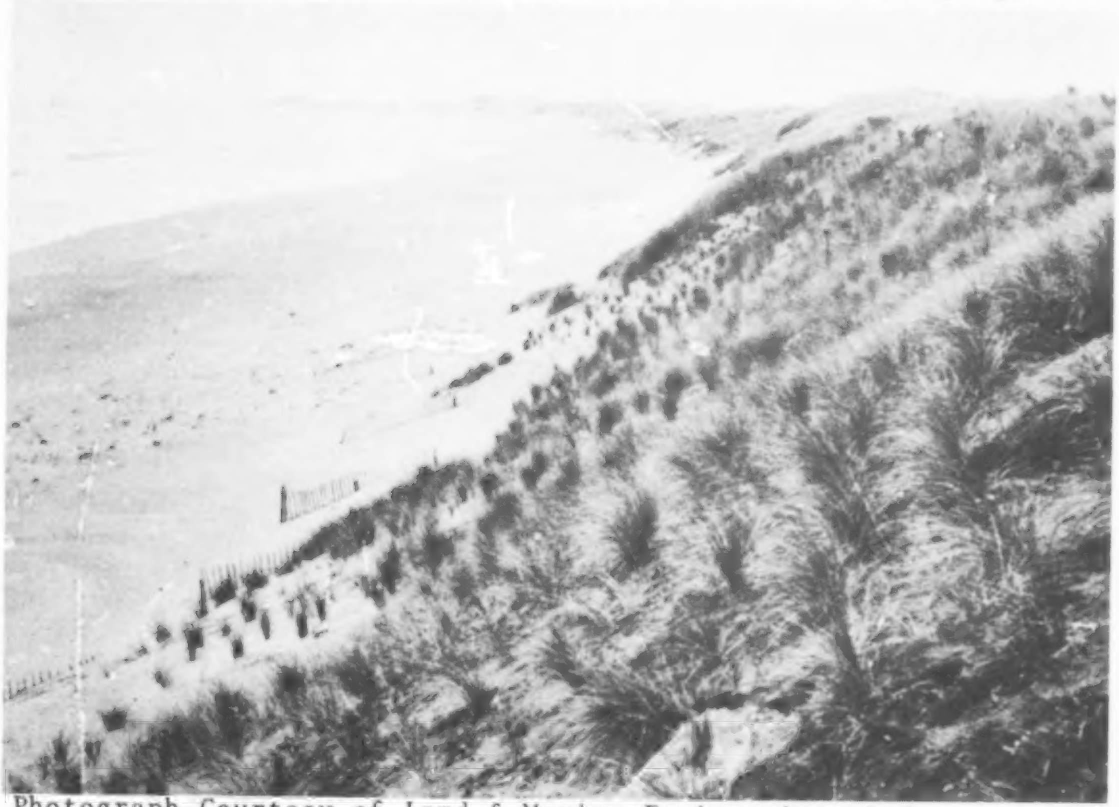
FIGURE 126. Dune Replanting. Looking south.



Photograph Courtesy of Land & Marine Engineering, Ltd., Merseyside, England.

FIGURE 127. Pipeline Right-of-Way after Reseeding. Looking landward across winter loch towards second dune ridge and escarpment.

Restoration Success: Figure 128 illustrates the restored dune face after the Marram grass had begun to grow and spread. An environmental assessment made of the area in July 1978 (approximately one year after restoration [Ritchie, 1978]) described the landfall and right-of-way restoration's progress.



Photograph Courtesy of Land & Marine Engineering, Ltd., Merseyside, England.

FIGURE 128. The Dune Face after Growth of Replanted Marram Grass had Begun. Looking south.

The beach appeared stable with accretion occurring, and the hand planted dune face and crest was exhibiting excellent Marram growth and spreading. The dune back slope, Winter Loch, and second sand ridge also showed good growth of sown grasses. The escarpment near the work site was the only location where damage was evident, primarily due to gullies resulting from improper terminal construction site drainage. This problem was to be addressed through the installation of appropriate drainage canals. No immediate action was felt necessary; ongoing monitoring to assess continued progess of restoration was recommended.

More recent observations indicate that the dune crest of the first ridge has been the most difficult area to restabilize. Wind scour on the surface has impeded sand accretion and thus the regrowth of Ammophila. Although reseeding has been attempted, establishment has been poor -- possibly due to surface instability and shifting. To deal with this problem, it has been suggested that dune sand without any type of "stabilizer" (e.g. clayey materials) should be placed as topsoil on dune crest. Fish net extended over the crest from the seaward dune face followed by Ammophila hand planting was recommended to stabilize the crest. After the Ammophila has taken hold, additional reseeding with grasses may lead to more effective crest restoration (Gimingham, 1980, personal communication).

SECTION 6

MINIMIZING IMPACTS AT FUTURE LANDFALL SITES

As illustrated by the landfall installations described in the preceding chapters, pipeline installation impacts can be minimized in two main ways: by using construction and restoration techniques appropriate to the physical constraints of a particular site; and by cooperative planning between government and industry to develop acceptable and effective regulations for a particular installation. This chapter summarizes the advantages and disadvantages of the various methods presented for minimizing the environmental effects of landfall installation and compares the effectiveness of different methods in similar ecosystems. The chapter considers:

- general technical installation and restoration methods applicable to any landfall situation;
- techniques appropriate to specific coastal ecosystems, including dunes, cobble beaches, rock cliffs, and wetlands;
- methods which address potential use conflicts; and
- planning approaches to future pipeline landfall installation regulation.

GENERAL INSTALLATION TECHNIQUES

There are a number of methods for minimizing installation impacts which are appropriate for use in any coastal system. Although it is recognized that it may not always be possible to employ these techniques, they should be considered in planning any pipeline installation. These methods focus on the scheduling and timing of construction and restoration, and limiting the total area disturbed.

TECHNICAL METHOD #1: Schedule to Avoid Key Ecological Seasons

Pipeline installation should be scheduled to minimize adverse environmental impacts where practicable. Construction during fish and bird migration and during mating seasons should be avoided wherever possible. This avoidance technique was successfully employed at the Menai Straits, Wales crossing, an important bird habitat, where a late summer installation was scheduled to avoid the indigenous bird mating season. (Surveys taken by an environmental interest group before and after installation indicated no significant changes in bird populations.)

Scheduling during periods of lowest biological productivity may also be considered to minimize impacts. Lowest productivity, however, usually occurs during the winter months -- the most hazardous time for pipelaying operations. Frequently, therefore, summer construction is required, even though the risk of environmental damage may be greater. For example, installation of the St. Fergus landfalls was undertaken in the summer months (June, July and August), the annual period when, traditionally, the North Sea is the least hazardous for nearshore construction activity. Even then, however, FLAGS line trenching in the surf and nearshore zones was delayed due to unfavorable weather conditions.

TECHNICAL METHOD #2: Minimize the Size of the Area Affected

Minimizing the size of the area affected by pipeline construction will minimize the extent of damage to the landfall ecosystem. This can be accomplished by limiting construction access to specific, well-defined corridors, and storing required construction materials in specified areas projected to be least affected by construction activity. (Practical requirements for pipeline construction and installation safety must also be considered in determining any construction site's size.)

This method is particularly valuable in very fragile coastal ecosystems, such as wetlands, where vegetation may not quickly recover. This was illustrated by the Frigg and FLAGS landfalls at St. Fergus where a seasonally flooded wetland (the Winter Loch) separated the beach from the gas processing terminal, which served as a staging area for landfall construction activities. When the first line (Frigg) was installed, construction vehicles were not strictly confined to specific corridors and as a result, gained access to the beach over a wide area of the Winter Loch. In addition, sand excavated from the beach was stored on the loch, affecting additional wetland acreage. Learning from this experience, the FLAGS line construction activity was limited to a specifically designated corridor whose boundaries were fenced to prevent access to other areas on the loch. This "corridor" was constructed of excavated beach and dune sand, thus serving the dual purpose of providing construction access and acting as a prime storage area for reconstruction materials. Although the areas of the Winter Loch affected by both installations are expected to recover, a significantly shorter recovery time is anticipated for the FLAGS line area.

Minimizing the amount of area directly affected by installation activities may not prove so important in areas in which a quick, natural recovery is anticipated. This was the case at the Long Beach, Grand Isle, and Whiskey Pass sites, where natural processes quickly resorted and restored beach sediments to their original distribution and equilibrium. This was also illustrated at the grassland portion of the Menai Straits crossing, where natural vegetation was easily restored by reseeding.

The physical characteristics of a site may themselves also limit the amount of area disturbed, in some cases, to a less than optimal size for pipeline construction. This was the case at the Anglesey terminal, where the size of the staging site (only one acre) confined the length of "made-up" pipe strings to only four joints. This in turn lengthened the time necessary to construct and install the line, increasing the length of time the pipe lay empty on the bottom and thus the hazard of pipe breakage.

TECHNICAL METHOD #3: Restore the Land/Water Interface Area Immediately

To minimize long-term effects, it is desirable to restore the landfall area immediately adjacent to the water as quickly as possible. This is particularly important in highly dynamic coastal systems where an exposed pipeline may be subject to possible damage from tides or waves; or where important landward coastal features (dunes, wetlands, etc.) may be exposed to wave or tidal damage if not protected by the shoreline system. The value of immediate restoration was well illustrated at the LOOP landfall which, only a few months after installation and beach restoration, was struck by a hurricane. The immediate beach restoration, however, prevented damage both to the wetland landward of the beach and to the pipeline itself which might have ruptured if exposed.

TECHNICAL METHOD #4: Restore the Entire Affected Area Physically and Ecologically

After completion of the installation, the entire landfall area should be restored to a condition as closely approximating the original as possible. This restoration would include as possible:

- Refilling the trench with native materials. Where insufficient quantities are available, materials of like characteristics should be chosen for subsurface layers, with original materials used, if available, in surface layers;
- Returning the area to original topography;
- Restoring original drainage patterns; and
- Replanting with indigenous plant species.

TECHNIQUES FOR SPECIFIC COASTAL SYSTEMS

Certain coastal ecosystems require few specialized technical methods to restore to original conditions beyond those outlined above. These areas are generally sandy, stable or protected segments of coastline with no important or unusual topographic features or vegetation. These coastal areas include flat or gently sloping beaches with no dunes (e.g. Long Beach, L.I., Grand Isle, LA and Whiskey Pass, LA) and industrially developed waterfront areas (such as the Morgan, NJ site). The presence of other coastal features may require use of more specialized restoration methods to assure more complete functional and aesthetic recovery. Features which may require additional attention include: dunes, cobble beaches, rock cliffs, and wetlands.

Dunes

The general method of restoration to original topography may not be sufficient to assure complete dune recovery, particularly in coastal areas prone to wind or wave erosion. If a pipeline is to be installed across an erosion-prone shoreline, the landfall dunes may require additional stabilization to aid their return to original conditions.

Two basic artificial stabilization techniques were successfully used in the landfall examples for dune restoration. One technique, used at both the Cruden Bay and St. Fergus landfalls, emphasizes stabilizing the internal dune structure by placing support devices inside the dune. At Cruden Bay, the Christmas tree tops and at St. Fergus, concrete gabions, were placed in the pipeline trench prior to restoration of the duneline's topography. This technique was used primarily to address potential "worst case" situations of high wind and/or storm surge attack on the dunes.

The second artificial technique relies on external stabilization of the dunes following reconstruction. At the landfalls cited above, fish netting was laid directly on the dune surface and snow fence accretion devices were installed to protect the recovering dunes from erosion.

Natural dune stabilization can be attempted by revegetation with original plant species. This can become a time-consuming and costly process for restoring the foredune and ridge because it often requires hand planting of individual plants of indigenous species. Successive plantings may be necessary because of high transplant mortality due to dune grass requirements for specific growth conditions which may not be present in reconstructed dunes. For example, Marram grass grows best under loose sand conditions, which eliminates the possibility of applying thin layers of "topsoil" (sand mixed with clay) over the dune surface -- a method frequently suggested for artificial stabilization. Despite the drawbacks, foredune revegetation is a highly recommended method for long-term dune stabilization; for example, hand planting was employed at Shell/Esso's FLAGS line installation very successfully.

Stabilization of the landward dune face is also often accomplished with revegetation. Unlike the foredune, however, labor-intensive hand planting is not necessarily required; if compatible with surrounding vegetation, reseeding may be used to initiate new plant growth. The reseeding method was used successfully at the Cruden Bay landfall, both on the back and fore sections of the dune and on the back section of the dunes disturbed by the FLAGS line installation.

Cobble Beaches

If beach cobble is sufficiently deep to allow trench excavation, standard restoration to original topography will likely be sufficient to prevent long-term effects from pipeline installation. If, however, cobble is underlain by bedrock, blasting may be required to trench to a depth sufficient for pipeline protection. Non-native materials would then be needed to refill the trench. Fill material duplicating the general size, density and shape distribution of the overlaying cobble would be the most logical choice to minimize aesthetic alteration and long-term effects. This restoration method was used at the Ninian pipeline landfalls, where "armour stones" (large, cubicle-shaped stones) were used to refill the trench. The refilled trench was then overlain with rockfill and shingle which approximated natural beach conditions.

Rock Cliffs

Where landfalls must be made on rock cliffs, blasting for trench excavation will be necessary. In this event, concrete must be used to "restore" the affected area, eliminating the possibility of returning the landfall to its original aesthetic condition. Concrete restorations of steep rock cliffs were necessary at both the Amlwch, Wales marine terminal the Firth Ness, Shetland Islands landfall.

Wetlands

Of all coastal ecosystems, wetlands -- particularly those which are very soft and muddy -- are probably the most difficult to restore to original aesthetic or functional condition. This is due in large part to the unique structure and function of wetlands, which is based on their loose highly water-saturated sediment structure. This sediment structure enables wetlands to serve two vital coastal functions: to act as a hydrologic buffer and filter at the fresh/salt water interface; and to provide substrate for a unique and highly productive vegetation community which requires the loose, highly saturated conditions for growth. When, however, sediments are excavated for pipeline trenches, they must be stored in piles, which results in water loss and compaction. In highly saturated "runny" wetland areas, large losses in sediment quantity occur, and it is generally impossible to refill the trench to original topography with excavated sediments. Even in areas of fairly firm sediments, some compaction and water loss can be expected, resulting in altered sediment structure in the trench once refilled. A number of methods may be considered to address these problems of wetland sediment restoration.

Until recently, canal refilling and wetland restoration was generally not attempted in areas of very runny sediments where the flotation method installation was used. Generally, excavated sediments were left in "spoil bank" piles on either of the trench, and the trench was left as a shallow open water canal. Restoration efforts concentrated on preventing disruption of wetland surface circulation. This was done by making breaks in the spoil banks at periodic intervals, and by constructing earthen or shell dikes at points where the canal intersected natural drainage creeks. Frequently, dikes were also constructed at periodic intervals along the canal itself to prevent boat traffic. These are the restoration methods used for the Whiskey Pass installation through the Louisiana coastal marsh.

For the more recent LOOP installation through similar very soft wetland, more extensive restoration efforts will be undertaken. These will include refilling the ditch with excavated materials and placing shell bulkheads at periodic intervals along the length of the canal. Rather than a straight canal, therefore, the affected area will be restored to a series of shallow water pockets, each two to three feet deep, separated by earthen dikes every 500 feet. It is anticipated that these measures will prevent major potential effects -- interference with tidal sheet flow and the creation of canal-type surface drainage.

Information gathered to date indicates that revegetation of refilled flotation canals has never been attempted. Restoration methods for the LOOP line were, however, chosen based in part on the assumption that vegetation from the adjoining wetlands would grow in to fill the canal. There is some disagreement on this point as many types of wetland vegetation in the LOOP line area are not known to colonize open water areas. Results of the LOOP restoration may help to resolve this issue.

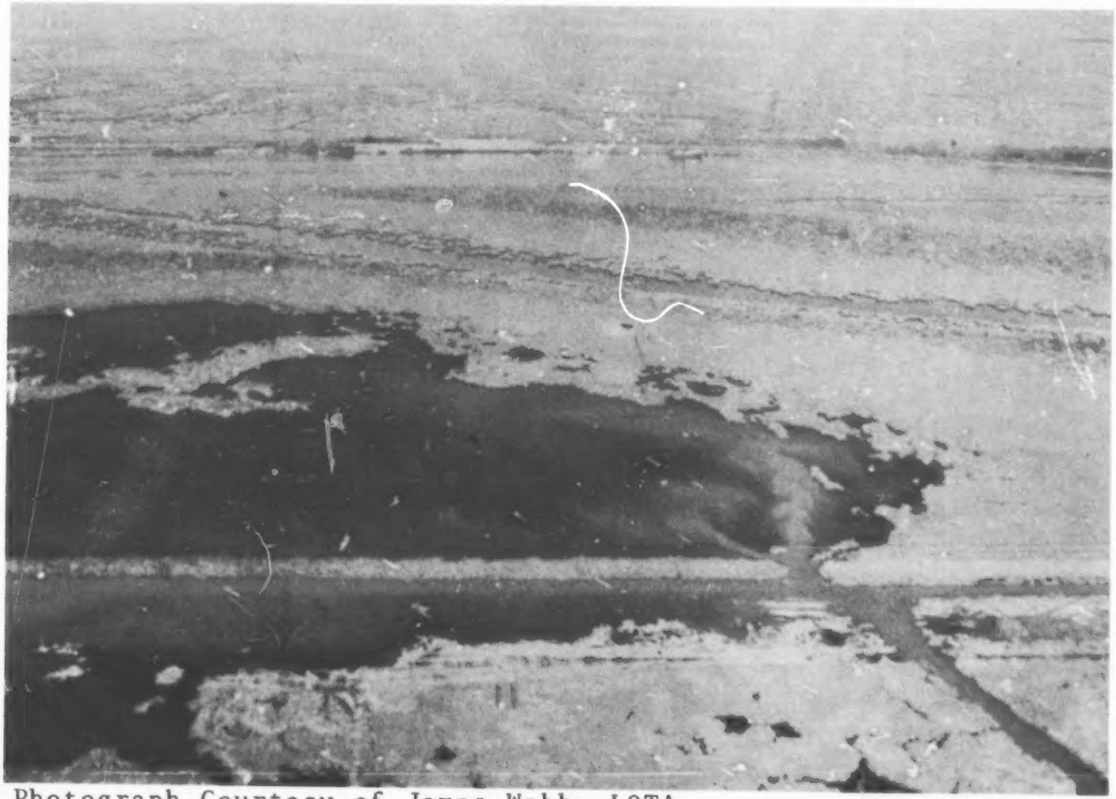
Another method for trench refilling in very muddy wetland may be to use non-native fill materials to augment originally excavated sediments. If this method were chosen, new fill would be placed in the trench first with original sediments used as the surface layer to return the canal to original topography. While this method might provide sufficient acceptable substrate for revegetation, effects on hydrologic functions are unknown.

In wetlands which are firm enough to support marsh buggy excavation equipment, there are generally sufficient quantities of sediment remaining after excavation to allow fairly complete trench refilling. Although no illustrations of this type of landfall restoration have been presented, previous studies indicate that this method generally results in no obvious open water and that, in fact, revegetation may ultimately hide any trace of the installation canal (McGinnis et al., 1972).

In wetlands with very firm sediments which may be flooded only seasonally, conventional land-based equipment can be used during dry seasons for trench excavation. Due to the drier sediment conditions, the trench can generally be successfully restored to original topography with excavated materials. This was the case at the St. Fergus landfalls, where the wetland, which flooded during fall and winter months, was excavated and restored during the dry summer season. Reseeding of the area with indigenous plant species was fairly successful in pipeline corridor revegetation.

There are other problems associated with wetland restoration which are linked to the installation activity itself. For example, excavation equipment other than conventional land-based machinery also contributes to installation impacts. In wetlands with soft sediments, large areas must be excavated to create canals to accommodate the barges required for pipeline trenching. Where the sediments are sufficiently firm to support marsh buggy-mounted equipment, much narrower pipeline canals can be dredged. Marsh buggies themselves, however, leave tracks across the marsh surface which may, over time, become open water areas. Another construction-related impact may result from the styrofoam floats attached to the line to maintain buoyancy during laying. If not collected immediately upon removal from the line, these floats may be scattered across a marsh by storms or winds, and may end up as uncollectable construction-related debris. This problem occurred at the LOOP line installation, where detached floats were blown across the marsh by a hurricane before they could be collected. (Floats can be seen as white dots on the marsh surface in Figures 106 and 111.)

Another interesting observation can be made on marsh construction methods based on the LOOP installation. A basic precept of marsh restoration is to prevent alteration of surface drainage. For the LOOP installation, this concept was also applied during construction; existing surface drainage creeks crossed while excavating the pipeline canal were not blocked. As a result, the highly turbid water associated with the excavation entered surface drainage waters. Figure 129 illustrates a segment of the LOOP pipeline canal where this mixing occurred. Based on this experience, short-term surface drainage blockage



Photograph Courtesy of James Webb, LOTA.

FIGURE 129. Turbidity Plume from Pipeline Canal.

may be considered appropriate at future installations to prevent this potential turbidity effect on waters adjacent to construction.

Use Conflicts

Potential conflicts between pipeline installation and other coastal zone uses may also be addressed with specific construction techniques. These uses include: recreation, roads and railroads, and commercial or sport fishing.

Generally, conflicts with recreational uses such as swimming can be avoided by scheduling the pipeline construction to occur after the recreational season is over. This technique is particularly useful in sandy beach areas where quick recovery is expected and in areas where the autumn climate allows sufficient time for installation and topographic restoration. The scheduling of the Long Beach, L.I. installation for September/October effectively prevented any recreational use disruption by installing the pipeline and completing the shoreline restoration between the end of one swim season and the beginning of the next. At Cruden Bay, potential impacts were anticipated from excavated sand associated with pipeline activity blowing onto a coastal golf course adjacent to the beach landfall. They were prevented by using various methods to stabilize the excavation and storage area; as a result, no distruption of golf course use occurred.

Special construction methods can also be used to prevent potential disruption of road and railroad use. These methods include boring under tracks of roadbeds or constructing temporary bridges over pipeline excavations. The success of these methods is illustrated at Morgan, N.J. and the Menai Straits crossing in Wales.

A pipeline shore approach and landfall may occasionally cross nearshore shellfish beds. Although the developer may restrict the use of heavy bottom trawling equipment after installation (to protect the line), he may allow harvesting all shellfish along the proposed route. This practice was used in those segments of the LOOP line which crossed oyster beds and at the Anglesey marine terminal shore approach, also a shellfishing area.

PLANNING TECHNIQUES

Prior to the mid-1970's, U.S. regulation of pipeline landfall installations was generally limited to pipeline safety specifications. Therefore, restoration work for the early 1970's installations described here was based generally on site restoration plans designed to protect the pipe from coastal hazards.* In the past 5-10 years, however, increased attention has been given to planning and regulating coastal development, emphasizing coastal ecosystem preservation and restoration. More recent installations -- the LOOP pipeline in Louisiana, and Cruden Bay and St. Fergus lines in the North Sea -- illustrate this increased government participation in pipeline landfall planning and regulation. The success of these installations can be attributed in large part to continuing interaction between regulators and developers thoughout landfall plan development. The following are the key "common threads" in planning and developing site restoration stipulations which were used at both these installations. These planning procedures may considered as examples from which future specific landfall installation regulations may be developed.

PLANNING METHOD #1: Site Selection

A site having natural (physical/geological/biological) characteristics which minimize the adverse environmental consequences of pipeline installation and adverse environmental consequences of pipeline installation and restoration should be chosen wherever possible. Preferred sites would generally be sandy, stable or protected coastal areas with no important or unusual topographic features or vegetation, such as flat or gently sloping beaches with no dunes or industrially developed waterfront areas.

It is recognized, however, that in some circumstances, sites with less preferable environmental characteristics must be chosen. The remaining methods** presented may be considered to minimize effects once a site has been selected.

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* It should be noted that these landfall restorations -- in particular, those made on beaches -- were also very successful.

** These methods, as applied to the Cruden Bay and St. Fergus landfall installations, were described in detail in two papers by Dr. William Ritchie, a Scottish ecologist who participated in environmental assessment and restoration plan development at the sites. Based on these experiences, he prepared "Environmental Problems Associated with a Pipeline Landfall in Coastal Dunes at Cruden Bay, Aberdeenshire, Scotland" (1974) and "Environmental Aspects of Oil and Gas Pipeline Landfalls in Northeast Scotland" (1980). The observations presented in these papers form the basis for the remainder of this discussion.

PLANNING METHOD #2: Environmental Assessment Preparation

The preparation of a technical environmental assessment (EA) for a chosen landfall site is a valuable method of identifying major potential installation impacts and information needs prior to construction. From an EA, stipulations for restoration can be developed to address specific environmental concerns at the chosen landfall site. EAs were effectively used at both the FLAGS and the LOOP lines to develop restoration plans appropriate to the specific problems anticipated at each site.

The following types of surveys were outlined in Ritchie (1974) as valuable for inclusions in an environmental assessment:

1. A vegetation survey before work begins. Vegetation is the best single index of environmental conditions.
2. A geomorphological survey of the local site in the context of the wider physiographic system. Note the process/form relationships in the area.
3. A large-scale gridded topographical survey of the site. The is an invaluable reference document and avoids ambiguity in carrying out instructions.

There may be certain problems (such as time and information limitations), however, in preparing environmental assessments. Ritchie (1980) outlines some of these issues which were encountered in preparing EAs for the North Sea installations:

> On the one hand there is the need to collate existing information on the area. This may vary greatly in quality and quantity. There are gaps in basic environmental information. Accordingly, if time is available, it is necessary to obtain information by conducting surveys or commissioning particular studies. For some environmental variables, this is not possible, and it is necessary to make assessments that are based on theoretical knowledge and/or from indirect evidence. Experience also shows that should objections arise, they often revolve around what can only be described as vague issues and terminology. One may contrast, for example, an environmental impact such as produced by sound or heat radiation (these impacts are calculable and can be compared against statutory limits and regulations) with issues that derive from the opinion of an observer. The word "environment" itself is vague. Similarly, how does one assess a criticism that cites "disturbance to wildlife" or, how does one evaluate the effect on the scenic appearance of

an area? There is no easy way to resolve these arguments other than by discussion with the parties involved so that some consensus of opinion can be obtained. In the end, these issues have to be considered against relative, rather than absolute standards. Another issue which is worth stressing is the need for all parties to recognize that there will always be gaps in the environmental knowledge for any given area, and that these gaps cannot be filled in the time available, if at all.

PLANNING METHOD #3: Planning and Permitting Centralized in One Agency

Both LOOP and the FLAGS landfall permitting were centralized in a single agency, which coordinated permit review, developed permit stipulations, and monitored actual installation and restoration activities. For the LOOP project, state coordination and oversight is administered through the Louisiana Offshore Terminal Authority (LOTA) and federal through the U.S. Coast Guard. For the FLAGS line, the Banff and Buchan District Council served this function. In Scotland, government structure specifically supports a single agency approach to physical planning and permitting.* In Louisiana, the single agency was state-created to handle offshore deepwater port development, and it was through this agency that the pipeline installation regulation and permitting was coordinated.

The advantages to this permitting method are that it may minimize the time necessary to obtain permits and to obtain variances in original stipulations if necessary. It may also foster better communication between developers and regulators by clearly defining the key participants in the development of the entire range of installation regulations. The single agency approach to landfall permitting may not, however, be possible at future U.S. offshore petroleum pipeline installations; based on existing structure, numerous federal, state, and local agencies may be involved in issuing permits for specific landfall-related activities.

PLANNING METHOD #4: Ongoing Consultations Between Developers and Regulators

At both the LOOP and the FLAGS installations, developers and government officials consulted throughout the planning and installation of the pipelines. As a result, permit stipulations were developed based on consideration both of the environmental concerns at the landfalls and the technical needs and constraints of the installation activities. Direct interaction also allowed the flexibility to change original plans as the installation proceeded without lengthy permit renegotiation. For example, this flexibility allowed original FLAGS line installation plans to be altered when the installation contractor suggested causeway construction -- an environmentally superior method to the original storage and construction access stipulations stated in the permit. As pointed out in Ritchie (1980):

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* Other aspects of development (fire, safety, etc.) are subject to permitting by a variety of agencies.

> The success of the projects at Cruden Bay and St. Fergus can, at least partially, be related to the use of environmental assessment statements and similar documents but just as important has been the flexibility amd exchange of information that has been involved in producing, interpreting and discussing these documents.

PLANNING METHOD #5: Establishing Goals for Restoration

The LOOP and St. Fergus landfall restorations centered on prevention of impacts originally anticipated in the environmental assessments. Rather than expecting a complete replication of original conditions, however, restoration efforts focused on minimizing long-term effects. For example, the following goals were outlined for the St. Fergus restoration effort:

1. To recreate a physical morphology which is as stable as the original landforms.

2. To recreate an environment which has similar ecological characteristics.

3. To recreate a landscape which is aesthetically pleasing and similar to adjacent areas. This landscape would be free of obvious physical civil engineering works in the beach and dune zones and be free of pollution (Ritchie, 1975).

To prevent surface drainage alterations on the marsh, the Louisiana Offshore Terminal Authority (LOTA) required refilling and plugging of the pipeline trench. Although not exactly duplicating original conditions aesthetically, it is anticipated that this refilling will prevent disturbance to marsh functions.

The problems and limitations of restoration at the Cruden Bay and St. Fergus landfalls are summarized by Ritchie (1980):

> Environmental restoration is also a difficult problem. At St. Fergus, and to a lesser extent at Cruden Bay, it was also made clear from the outset that full environmental restoration was impossible. This was particularly true at St. Fergus where the eroding coastal dune and the maturity of the vegetation on the backslope and Winter Loch area created insurmountable difficulties for full and complete restoration programmes. The argument was presented that restoration should aim to produce an surface that was compatible and similar to adjacent areas. It was thought that in the fullness of time, natural forces would probably achieve an ecological situation that was increasingly similar to adjacent areas. It would be wrong for the writer of an environmental impact statement and the developer who contracts such a survey to claim that an exact replacement of a complex habitat and environment such as that pertaining to a changeable open beach and eroding, mature sand dunes would be attainable. Equally, it is unreasonable for a planning authority to expect such replication.

PLANNING METHOD #6: Long-Term Monitoring Programs

To assess the extent and duration of installation effects, regulation at both landfalls required a commitment on the part of the developer to long-term monitoring of the affected areas. At St. Fergus, five years of follow-up monitoring was recommended; at the LOOP installation, a 4-5 year intensive program is anticipated, with selected monitoring throughout the life of the project.

A SUMMARY OF RECOMMENDATIONS FOR FUTURE INSTALLATIONS

The experiences at both landfalls indicate that, working together, developers and regulators can generate, on a case-by-case basis, permit stipulations designed to address the specific unique environmental and technical constraints at a chosen landfall site. Although the long-term effects of the LOOP installation cannot be assessed because restoration has not been completed, it is noteworthy that this is one of the first efforts at functional restoration of coastal wetlands altered by creation of pipeline installation canals.

On the other hand, an initial assessment of Cruden Bay and St. Fergus landfall restoration success is possible because both have had a number of years (3-6) to recover. Ritchie (1980) concludes his discussion of the two landfall areas with the following summary of lessons to be learned from these two installations:

> Restoration and environmental work at Cruden Bay and St. Fergus has demonstrated the reciprocal advantages of environmental assessment and impact statements to the developer, the engineer and planner. It has also shown the value of early and informative discussions between the developer, site engineer, planning agencies and environmental consultants. It has also suggested the need for careful specific site selection in that some areas are manifestly easier to manage and restore than others. In this respect, it is possible to recommend that an environmental consultant should be used before the precise site is chosen. No new techniques have been developed as a result of these three operational situations, although the policy of pre-determining access and working areas has been a useful innovation. Otherwise, the actual programme consisted of using techniques and methods developed elsewhere; they have simply been modified to suit particular local conditions. It has also been demonstrated that after restoration there is a need for a continuing monitoring programme to last at least 5 years. It has also shown that the developer needs to accept a commitment to review the progress of restoration work particularly in such dynamic and potentially fragile environments as the coastal zone. Management does not end when the pipelines come ashore. The input of capital and personnel for such monitoring is not great, amounting to little more than a few visits each year but this small provision will provide considerable benefits. It will also serve to improve or consolidate the relationships between the local community, the planning authority and the developing agent.

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APPENDIX A

INDUSTRY PROCEDURES FOR PIPELINE LANDFALL SELECTION

by
Pipeline Industry Advisory Task Force
George G. Hughes Jr., Chairman

The initial planning for selection of pipeline routing and landfall is more general than specific and is used to identify, to the extent possible in advance, sites suitable for location of energy facilities. Normally several potential landfalls are selected which accommodate basic water and land requirements and which would facilitate onshore connections with related petroleum facilities such as pipelines, terminals, refineries etc., which provide access to energy markets. Most of the planning at this stage is done with the use of offshore navigation charts, city, county, state, and U.S.G.S topographic maps, along with pertinent data from any available sources. Consideration is given to the selection of landfalls that are generally compatible with pipeline construction and maintenance requirements, while minimizing onshore impacts. Effort is made to avoid, to the extent possible, areas of public concern such as congested areas, wildlife preserves, wilderness areas and other known sensitive areas. Social and economic effects, both positive and negative, are given full consideration in the planning process.

As exploratory and development drilling progress and it appears that a commercial discovery may be made, more specific planning is undertaken. The quantity and quality of the discovery will dictate the type of facility required and may also have a bearing on the desired landfall location. For example: a rather large discovery may dictate one landfall, while a rather small but still commercial discovery may suggest that a different landfall is preferable because of the required size of pipeline and quantity of oil or gas to be delivered at that specific location. Also, an oil discovery may not be of sufficient magnitude to economically justify a pipeline connection, and marine transportation may be the only feasible alternative.

The selection of a specific pipeline landfall demands the review and consideration of many factors. These factors include the offshore origin, the onshore destination, possible geotechnical problems and environmental impacts as well as safety and economic considerations. It is essential to understand that some tradeoffs and concessions are usually required. Route surveys are made on OCS protraction diagrams with a scale of one inch equals 4000 feet and are planned to meet the Bureau of Land Management's requirements for a geophysical hazard survey and an archaeological survey. Bottom profiles are made to determine the bottom configuration and sub-bottom profiles are run to a depth of about 25 or 50 feet. Side scan sonar is also undertaken to indicate any adjacent anomalies. Bottom cores are obtained in areas where it is deemed necessary to further evaluate the bottom bearing and stability conditions. A magnetometer survey is run to locate any magnetic anomalies such as pipelines, cable, wrecks, junk, debris, explosives, ammunition etc. Depending on survey conditions and anomaly size, detection may range up to 200 feet laterally from the survey point.

The size of the onshore location required for pipeline facilities will vary considerably depending on the type and quantity of offshore discovery. Numerous permit applications to federal, state, and local regulatory authorities are required; obtaining permits is generally quite time consuming. During this interim period, negotiations are begun to acquire the desired site for the landfall location and associated shore facilities. Sites may be acquired by either long term lease or by purchase.

The time span during this period may range from five to ten years. This allows sufficient time to gather available pertinent data from many sources. In areas where petroleum production has been active for many years most required data is generally available, whereas, in frontier areas, where exploration and production has not previously taken place, it will be necessary to conduct more tests and studies. Technical experts from the petroleum companies are used to a large degree, and where expertise in unfamiliar areas is required, the employment of any required specialists is undertaken. These experts are carefully selected, considering their unique specialty and particular knowledge in the technical area and geographical area involved.

The final selection of the landfall will result after consideration of many factors including all physical, geological and environmental constraints, use conflicts, permit requirements and economic and safety determinations. The required size of the landfall site will also vary depending on many factors and may range from a few acres to many times this amount.

Registers of Scotland

Appendix B

LEGAL AGREEMENT ON FLAGS LINE INSTALLATION

6659

AT EDINBURGH the Twenty first day of May Nineteen hundred and seventy six the Deed hereinafter reproduced was presented for registration in the Books of the Lords of Council and Session for preservation and execution and is registered in the said Books as follows:-

AGREEMENT

between

BANFF AND BUCHAN DISTRICT COUNCIL, St. Leonard's, Sandyhill Road, Banff, incorporated under the Local Government (Scotland) Act 1973 (the said Council and its successors and assignees being hereinafter referred to as "the Council") of the first part

and

SHELL U.K. LIMITED, a company incorporated under the Companies Acts and having their registered office at Shellmex House, Strand, London, W.C.1. (who and whose successors and assignees whomsoever are hereinafter referred to as "the Company") of the second part.

WHEREAS the Company have applied to the Council as Local Planning Authority for planning permission for development involving the construction of the landfall section of the Brent Gas Pipeline which includes inter alia laying a thirty-six inch diameter pipe from the sea through the sand dune shown delineated in brown on the plan annexed and executed as relative hereto, the Winter Loch shown delineated in blue on the said plan, the sandhills shown delineated in red on the said plan, and the landward escarpment shown delineated in yellow on the said plan, to the site of a proposed gas reception terminal at St. Fergus in the County of Aberdeen, and WHEREAS the Council are prepared to grant planning permission for the development subject inter alia to certain conditions which it is right and proper should be embodied in a written Agreement between the Council and the Company under the provisions of Section 50 of the Town and Country Planning (Scotland) Act 1972 and WHEREAS the Company have agreed to enter into such an Agreement with the Council: NOW THEREFORE the Parties hereto HAVE AGREED and DO HEREBY AGREE as follows, videlicet:-

(PAGE TWO)

(ONE) It shall be an obligation on the Company to carry out, implement, comply with and adhere to the following conditions before, during and after development as appropriate, all to the satisfaction of the Director of Planning and Development;

(a) Prior to the commencement of development on the area of ground which is the subject of the application for planning permission, (which said area is shown delineated in purple on the said plan and is hereinafter referred to as "the Site"), the Company shall submit to the Council's Director of Planning and Development, a longitudinal profile of the bottom of the entire Winter Loch.

(b) Prior to the commencement of development, all details regarding the method of pipe pull to be used (whether onshore or offshore) shall be submitted to and approved by the Director of Planning and Development insofar as relating to their environmental aspects and impact and planning considerations generally.

(c) The Company shall, at intervals as indicated by the Director of Planning and Development, submit to him profiles of the winter beach, sandhills, and landward escarpment.

(d) The side slopes of the dune exposed by the cut made to allow passage through the dune of the said pipe shall, on exposure, be immediately sprayed by the Company with bitumen compound sufficient to effectively minimise wind erosion.

(e) The sand requiring to be removed by the Company from the dune area shown delineated and coloured brown on the said plan shall be removed in two stages, videlicet:-

the first stage shall consist of the removal of the top twenty-five centimetres of sand and vegetation and the storage thereof within one or other of the spoil areas shown delineated in green on the said plan, but always separate from any other spoil. The storage of this top layer shall be contained by the Company within a clearly delineated area acceptable to the Director of Planning and Development. The remainder of the sand requiring to be removed by the Company from the dune area shall also be stored by them in one or other of the said spoil areas.

(f) The sand requiring to be removed by the Company from the sandhills and landward escarpment areas shown delineated and coloured red and yellow respectively on the said plan shall be removed in two stages; the first stage shall consist of the removal of the top fifty centimetres of vegetation and topsoil or sand and the storage thereof within a clearly delineated area acceptable to the Director of Planning and Development entirely within one or other of the said spoil areas but always separate from any other spoil. The remaining sand removed by the Company from the landward escarpment and sandhills shall also be stored entirely in one or other of the spoil areas, but kept separate from the top twenty-five centimetres of sand removed as aforesaid from the dune and the top fifty centimetres of topsoil and sand removed as aforesaid from the sandhills and landward escarpment.

(g) No spoil shall extend entirely across the said Winter Loch.

(h) The height of any spoil stored as hereinbefore mentioned shall not exceed five metres above existing ground level and the surface of all such spoil shall be lightly sprayed with a bitumen compound sufficient to ensure the prevention of erosion.

(i) Apart from the storage of spoil in accordance with the foregoing conditions, no storage of spoil or materials, machinery or equipment of any nature whatsoever shall be permitted on the site, with the exception of the upper plateau surface lying at the extreme West of the site, that is to say that area of ground situated to the West of a line drawn along the ten metre contour on the landward escarpment shown delineated in orange on the said plan, without the prior written agreement of the Director of Planning and Development.

(j) Immediately upon commencement of development, the Company shall implement, to the satisfaction of the Council's Director of Environmental Health, a system of refuse and waste collection and disposal which shall continue until all restoration work as aftermentioned is completed.

(k) Any water pumped from the pipeline trench shall only be discharged directly on to the beach to the East of the dune.

(l) All access tracks across the site, for vehicles of any kind whatsoever, shall be strictly limited in number, clearly defined and marked on the site, approved in writing by the Director of Planning and Development and fenced, all before use.

(m) All other areas which are to be used by vehicles shall be clearly defined and marked on the site and fenced before commencement of development.

(n) The said pipe which is to be laid shall be buried to a sufficient depth to prevent its exposure, either in whole or in part, in winter conditions.

(TWO) In addition to and without prejudice to the foregoing conditions, the Company hereby undertake that, immediately the said pipe has been satisfactorily laid and development has been completed, they will restore the entire site to its original condition, and in particular, but without prejudice to the foregoing generality, will ensure that the following conditions, which are conditions precedent for the successful restoration of the site, shall be carried out, implemented, adhered to and complied with, all to the satisfaction of the Director of Planning and Development:-

(a) The breach to be made in the dune shall be strengthened by the Company by the insertion, at an early stage and as an integral part of the reinstatement of the site, of a gabion wall, the design and dimensions of which must be approved in writing by the Director of Planning and Development prior to insertion.

(b) The Winter Loch will be restored to the contours shown in the longitudinal profile of the loch bottom submitted by the Company to the Director of Planning and Development in accordance with the provisions of Clause (ONE) (a) hereof.

(c) The winter beach, sandhills and landward escarpment will be completely restored in accordance with the contours shown in the profiles thereof submitted at regular intervals by the Company to the Director of Planning and Development in accordance with the provisions of Clause (ONE) (c) hereof.

(d) All topsoil to be used in restoration of the dune shall be of a suitable composition and depth to permit the free rooting of Marram grass.

(e) Before replanting of the site as aftermentioned is commenced, the site will require to be restored to its original physical state and configuration, and in accordance with the contours shown in all profiles as hereinbefore mentioned.

(f) Immediately after the physical restoration referred to in Clause (TWO) (e) hereof has been carried out, the face, crest and ridge of the dune shall be stabilised and planted with Marram grass and all other surfaces within the site, if disturbed in any way whatsoever, by development, shall be stabilised, fertilised and planted in accordance with a programme to be prepared by the Company and approved in writing by the Director of Planning and Development.

(g) All vegetation in any disturbed areas as mentioned in Clause (TWO) (f) hereof shall be restored, and the progress of the restoration programme shall be monitored by the Company at regular intervals and further replanting shall be carried out by them as thought necessary in the opinion of the Director of Planning and Development to ensure that the entire site is restored to its original condition.

(h) The Company hereby bind themselves to remain responsible for the condition and satisfactory restoration of the site until vegetation is re-established, including the re-establishment of all existing trees, and in any event for a minimum of five years after the restoration referred to in Clause (TWO)(e) hereof has been carried out.

(i) Additional planting shall be carried out in accordance with a landscaping plan to be submitted to the Director of Planning and Development for approval within 3 months of the commencement of development. All planting shall be carried out not later than the first planting season following upon the commencement of development and shall thereafter be maintained by the Company in accordance with the code of good forestry practice.

(j) After the restoration referred to in Clause (TWO)(e) hereof has been carried out, all artifacts, waste, rock fragments, hardcore, and any other refuse or spoil, shall be removed from the site area or disposed of, all to the satisfaction of the Director of Planning and Development.

(k) On completion of all works, including those of restoration, the natural drainage system of the site shall be restored.

(THREE) The Company shall obtain a fiduciary guarantee from an established bank or insurance company acceptable to the Council, inter alia guaranteeing the due and complete performance by the Company of the whole works and obligations herein contracted and agreed to be done and fulfilled by them and in particular, but without prejudice to the foregoing generality, guaranteeing to make payment to the Council of the amount of all loss, injury or damage of whatever nature, financial or otherwise, which the Council may incur or be put to through or in consequence of any failure, neglect, omission or refusal on the part of the Company either duly to complete and fulfil the aforesaid works for which application for planning permission was made, or to perform, comply with or observe the terms and conditions of this Agreement. Declaring however that the total amount which the said bank or insurance company shall be liable to pay to the Council shall not exceed

Two Hundred and Fifty Thousand Pounds (£250,000).

(FOUR) The Council shall be the sole arbiters in deciding whether the conditions contained in this Agreement are being contravened or not implemented, and they shall, if they so decide, bo immediately entitled to take such action as they alone think necessary, after having consulted with a mutually-agreed Environmental Adviser to remedy any such contravention or non-implementation (including carrying out any works themselves or through their servants or Agents). In addition, they shall be entitled to recover from the Company all costs which they may thereby incur.

(FIVE) In the event of the Company going into liquidation, whether voluntary or otherwise (other than a voluntary liquidation for the purpose of reconstruction or amalgamation), or becoming Notour Bankrupt, or signing a trust deed for behoof of creditors, or having a warrant of sequestration pronounced with reference to their estates, then in any of these events the Council shall immediately be entitled to take such action as they think fit to ensure compliance with and implementation of the conditions incorporated in this Agreement and recovery of any costs thereby incurred.

(SIX) The company shall free, relieve and indemnify the Council in respect of any loss, injury or damage whatsoever, however sustained, attributable to or arising out of development of the site either by the Company or by the Council in connection with the provisions of this Agreement. Decalaring however that the Company will not be liable in respect of any loss, injury or damage caused by or as a result of the negligence of the Council, its employees, agents or servants, or persons for whom it is responsible.

(SEVEN) The Company shall at all times, after having been given notification by the Council, permit the Council and its agents, officials, employees, and any other persons authorised by it or its agents to enter upon and have access to the site at any time for the purpose of (a) viewing and examining the progress of development; (b) ascertaining the condition of the site, both inside and outside or any part thereof; and (c) taking such action as is referred to in Clauses (FOUR) and (FIVE) hereof.

(EIGHT) Any reference to works or development to be carried out by the Company shall include a reference to works being carried out or done by employees, sub-contractors, servants, agents or any other person or body employed by the Company or for whom the Company is responsible.

(NINE) Notwithstanding the foregoing provisions of this Agreement it is hereby declared that any or all of the conditions and obligations herein contained may be altered or amended by written agreement between the Company and the Director of Planning and Development.

(TEN) The powers and remedies available to the Council under this Agreement are in addition to and without prejudice to and not in substitution for all other powers and remedies competent to the Council by Statute or Common Law.

(ELEVEN) In construing these presents, the following expressions have the meanings hereby assigned to them respectively, that is to say:- "spoil" means any sand, topsoil, vegetation, earth or other substance excavated from the site; "development" has the meaning assigned to it by Section 19 of the Town and Country Planning (Scotland) Act 1972.

(TWELVE) The Parties hereto hereby consent to registration hereof for preservation and execution:

IN WITNESS WHEREOF these presents typewritten on this and the nine preceding pages are, together with the plan hereto annexed, executed as follows, videlicet:- they are sealed with the Common Seal of the said Shell U.K. Limited and subscribed for them and on their behalf by William Edwin Bell, one of their Directors, and by Gordon Stanley Simpson, their Secretary, both together at London on the twenty-first day of April Nineteen Hundred and Seventy-Six; and they are sealed with the Common Seal of the said Banff and Buchan District Council and subscribed for them and on their behalf by William Ruxton Cruickshank and Norman Cowie, two of their Members, and by Ronald William Jackson, Depute Director of Administration and Legal Services and Proper Officer, all together at Banff on the fourth day of May Nineteen Hundred and Seventy-Six.

Director W Bell
Secretary G S Simpson

Member Wm R Cruickshank
Member Norman Cowie
Proper Officer R Jackson

AND the said Lords grant Warrant for all lawful execution hereon.

EXTRACTED by me having commission to that effect from the Keeper of the Registers of Scotland.

Catherine L. Clark